November 24, 2021

The Honorable Chair and Members of the
Hawai‘i Public Utilities Commission
465 South King Street
Kekuanaoa Building, 1st Floor
Honolulu, Hawai‘i 96813

Dear Commissioners:

Subject: Docket No. 2007-0341 – Review of Demand-Side Management Reports and Requests for Program Modifications – Hawaiian Electric Company, Inc. Modification and Evaluation Report

In accordance with Order No. 23717*,* filed October 12, 2007 in the subject proceeding, attached is Hawaiian Electric Company, Inc.'s ("Hawaiian Electric" or the "Company") Annual Program Modification and Evaluation Report ("M&E Report") for its Commercial and Industrial Direct Load Control ("CIDLC") program, Residential Direct Load Control ("RDLC") program, Fast Demand Response Pilot ("Fast DR") Program, and implementation of the Demand Response ("DR") Portfolio. The M&E Report provides information on 2022 forecasted grid services amounts, forecasted program budgets, 2021 Evaluation, Measurement, and Verfication ("EM&V") Report, and key activities for implementing the DR Portfolio.

Sincerely,

/S/ Kevin M. Katsura

Kevin M. Katsura
Director
Regulatory Non-Rate Proceedings

Attachment

c: Division of Consumer Advocacy

HAWAIIAN ELECTRIC COMPANY, INC.
MAUI ELECTRIC COMPANY, LIMITED
HAWAI'I ELECTRIC LIGHT COMPANY, INC.

DEMAND-SIDE MANAGEMENT PROGRAMS MODIFICATION AND EVALUATION REPORT

November 24, 2021

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PREFACE

In its Demand-Side Management ("DSM") Program applications, Hawaiian Electric Company, Inc. ("Hawaiian Electric"), Maui Electric Company, Limited ("Maui Electric"), and Hawaiʻi Electric Light Company, Inc. ("Hawaiʻi Electric Light") (collectively, the "Hawaiian Electric Companies" or "Companies"), proposed to file two annual reports with the Hawaiʻi Public Utilities Commission ("Commission"):[1]

(1) The Modification and Evaluation Report ("M&E Report") filed by November 30th of each year; and
(2) The Accomplishments and Surcharge Report ("A&S Report") filed in March following the end of each calendar year.

The M&E Report is considered a prospective view of the DSM program(s) operations for the next calendar year and serves the following purposes:

- DSM Program(s) are defined in this report as existing Demand Response programs and grid service programs executed by contracting with aggregators.
- Provides an updated forecast of the budgets and goals;
- Describes the modifications to the program(s) that the Companies propose to implement; and
- Provides the results of evaluation studies, which can also serve as the basis for potential modifications to budgets, goals, and program implementation strategy.

The A&S Report is considered a financial reporting of the DSM program(s)' performance from the prior calendar year and serves the following purposes:

- Documents the accomplishments of the DSM programs, including an accounting of the demand savings impacts, equipment installations, and recorded program expenditures; and
- Provides an update of the cost-effectiveness of the program(s) based upon recorded program expenditures and measure adoptions. The Companies expect to file their next A&S Report on or about March 30, 2022, in Docket No. 2007-0341.

[1] In Order No. 23717, filed on October 12, 2007, the Commission opened Docket No. 2007-0341 instituting a proceeding to review Hawaiian Electric's DSM reports and requests for program modifications, and ordered that such reports and requests be filed in the subject docket. This M&E Report is filed pursuant to that Order.

I. Background

On February 27, 2019, the Commission issued Order No. 36187 in Docket No. 2017-0352 providing guidance to issue a Grid Service Request for Proposal ("RFP") concurrent to the Phase 2 RFP for Dispatchable and Renewable Generation.

On March 18, 2019 in Docket No. 2007-0341, the Companies filed a request for Commission approval of the Grid Service Purchase Agreement ("GSPA") contract with Open Access Technology International Inc. ("OATI"), and its related DR Portfolio Variable Costs to be recovered through the DSM Surcharge.

On August 5, 2019, the Commission issued Order No. 36453 in Docket No. 2015-0412 approving the Demand Response Adjustment Clause ("DRAC"). On August 22, 2019, the Companies requested that the filing date of the first DRAC be delayed in order to align with a scheduled quarterly filing. On September 3, 2019, the Commission issued Order No. 36499 approving the new filing date for the DRAC. Subsequently the Companies filed their first DRAC on October 25, 2019 under the new investigative Docket No. 2019-0323.

On August 9, 2019, the Commission issued Order No. 36467 in Docket No. 2007-0341, approving the GSPA contract with OATI ("GSPA1"), and its related DR Portfolio Variable Costs to be recovered through the DSM Surcharge. Order No. 36467 in Docket No. 2007-0341 approved OATI as the aggregator for the first round of GSPA contracts ("GSPA1 Aggregators").

On August 19, 2019, the Commission issued Order No. 36476 closing the DER Docket No. 2014-0192 and on September 3, 2019 the Commission issued Order No. 36499 closing the Demand Response Docket No. 2015-0412. Subsequently on September 24, 2019, the Commission issued Order No. 36538 which opened the Investigative docket for Distributed Energy Resources Docket No. 2019-0323.

In accordance with Order No. 36474 issued in Docket No. 2017-0352, the Companies issued RFP No. 103119-02 Grid Services from Customer-sited Distributed Energy Resources. The Companies made their selection on January 9, 2020 and initiate contract negotiation with multiple aggregator vendors. On July 9, 2020, the Companies submitted a request for cost recovery for the executed GSPA contracts negotiated in RFP No. 103119-02 ("GSPA2"). OATI and Swell Energy, Inc. ("Swell") executed GSPA2 contracts ("GSPA2 Aggregators") in Docket No. 2007-0341.

On April 9, 2020 the Commission issued Order No. 37066 in Docket No. 2019-0323 ("Order 37066"), establishing three tracks within the docket, the DER Program Track, Advanced Rate Design ("ARD") Track, and Technical Track. The Commission identified the following objectives for the DER Program Track: (1) Design and implement long-term DER programs, (2) Develop a transition plan for interim DER programs. Order 37066 also identifies the Commission's strategic outcomes for this track:

(1) Simple options for long-term DER tariffs, including a standard DER tariff and an advanced grid services tariff; (2) Clear and fair Transition Plan for customers in CSS, CGS, CGS+ and Smart Export to migrate to long-term tariffs; and (3) Addressing NEM customers. These strategic outcomes must take into consideration the existing demand response (i.e. grid service) programs and existing or future grid service procurements that will inform the advanced grid service tariff and DER transition plans.

On December 31, 2020, the Commission issued Order No. 37523 in the subject proceeding approving cost recovery for GSPA2 Aggregators.

On June 8, 2021 and June 30, 2021, the Commission issued Decision and Order No. 37816 and Decision and Order No. 37853 ("D&O 37853"), respectively, approving an Emergency Demand Response Program ("EDRP"), the Scheduled Dispatch Program Rider ("SDP"), and directed Hawaiian Electric to commence replacement activities to return the O'ahu Fast DR program back to its full 7-megawatt ("MW") capacity in Docket No. 2019-0323

On August 3, 2021, the Commission issued Ordered 37893, approving (with modifications) the Companies' O'ahu Grid Services RFP for 60 MWs of Capacity Reduction and 12 MWs of Fast Frequency Response ("GSPA3 RFP") to help mitigate the risk of a potential future capacity reserve shortfall.[2]

II. Summary of PY2022 CER Operations

The Commission has set forth directives for Customer Energy Resources ("CER") Operations cost recovery, and its preference for CER Operations costs to be reflected in base rates, rather than collected through a separate surcharge.[3] Aligned with this approach, for the program year 2022 ("PY2022"), Hawaiian Electric has included $4.7 million in base rates to manage the existing programs and Maui Electric has included $408,000 in base rates for its existing DR program. Of the proposed DR budget, $3.74 million and $384,000 for Hawaiian Electric and Maui Electric respectively will be managed to the DRAC and filed and reconciled quarterly.[4] Hawaiian Electric will continue to seek surcharge recovery of the remaining budget request not included in base rate until the next rate case, as presented in Exhibit A.

There are no proposed modifications to the existing Hawaiian Electric DR programs for 2022.

In 2022, the Companies will support aggregators recovering from Force Majeure due to the effects of COVID-19 and continue to support GSPA2 Aggregator participant enrollment. In addition, the Companies are seeking to add to the DR Portfolio by

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[2] See Docket No. 2017-0352, Order No. 37893, filed on August 3, 2021.
[3] See Docket No. 2007-0341, Order No. 33027 filed July 28, 2015, at 57-59.
[4] See Docket No. 2015-0412, Order No. 36453 filed August 5, 2019 approving the DRAC.

contracting aggregators awarded under the GSPA3 RFP, pending contract negotiations and subsequent Commission approval.

The Companies will maintain the existing EnergyScout Maui Fast DR programs while taking steps to transition customers from the existing EnergyScout programs to new programmatic solutions. As a first step, the Companies are issuing an RFP to transition existing EnergyScout Program participants to a smarter, two-way communicating device and associated infrastructure to enable the delivery of a variety of grid services. For O‘ahu Fast DR, the Companies will seek 2.722 MW of capacity to replenish the program.

The Demand Response Management System ("DRMS") responsible for the control of the available CER resources will continue to be upgraded with new features, including integration with inverter-based resources. Other initiatives, such as a customer's ability to self-aggregate resources, and non-wire alternative ("NWA") grid upgrades using CER will continue to be investigated.

In late 2019, the Companies selected an Evaluation Measurement & Verification ("EM&V") consultant, The Cadmus Group Inc. ("Cadmus"), and has since worked on the Planning and Execution stage of their impact analysis of GSPA1 Aggregator with OATI. Cadmus provided a report to the Companies, attached as Exhibit B. Cadmus completed the impact studies, forecast performance, and aggregator performance on OATI's water heater load.

A. Summary of CER Operations Programs

1. Summary of PY2022 Hawaiian Electric Budget

Table III-1 below provides a summary of the PY2022 Hawaiian Electric Budget with a high-level breakdown of the incremental and base costs for the existing CER Operations programs (see the attached Exhibit A for additional details). The existing CER Operations program budgets are presented for informational purposes only, as they are now included in base rates. Of the proposed Hawaiian Electric budget, $3.74 million of incentive will be managed to the DRAC and filed and reconciled quarterly. The DR Portfolio cost shown below is the sum of the costs for approved GSPA aggregators. Approved GSPAs will provide multiple grid services; the Companies will only submit summed DR Portfolio costs to avoid any procurement advantage for future potential aggregators.

Table II-1
Summary of PY2022 Hawaiian Electric Budget ($)

	Incremental	Base	Total
RDLC Program	$0	$1,788,840	$1,788,840
CIDLC Program	$0	$2,494,000	$2,494,000
Fast DR (Hawaiian Electric)	$0	$440,000	$440,000
DR Portfolio	$5,837,647	$0	$5,837,647
Total:	$5,837,647	$4,722,840	$10,560,487

2. Summary of PY2022 Maui Electric Budget

Table III-2 below provides a summary of the PY2022 Maui Electric Budget with a high-level breakdown of the incremental and base costs for the existing CER Operations (see the attached Exhibit A for additional details). The existing CER Operations budgets are presented for informational purposes only, as they are now included in base rates. Of the proposed Maui Electric budget, $384,000 will be managed to the DRAC and filed and reconciled quarterly. The DR Portfolio cost shown below is the sum of the costs for approved GSPA aggregators. Approved GSPAs will provide multiple grid services; the Companies will only submit summed DR Portfolio costs to avoid any procurement advantage for future potential aggregators.

Table II-2
Summary of Total PY2022 Maui Electric Budget ($)

	Incremental	Base	Total
Fast DR (Maui Electric)	$0	$408,000	$408,000
DR Portfolio	$1,497,228	$0	$1,497,228
Total:	$1,497,228	$408,000	$1,905,228

3. Summary of PY2022 Hawai‘i Electric Light Budget

Table III-3 below provides a summary of the PY2022 Hawai‘i Electric Light Budget with a high-level breakdown of the incremental and base costs. The DR Portfolio cost shown below is the sum of the costs for approved GSPA aggregators. Approved GSPAs will provide multiple grid services; the Companies will only submit summed DR Portfolio costs to avoid any procurement advantage for future potential aggregators.

Table II-3
Summary of Total PY2022 Hawai‘i Electric Light Budget ($)

	Incremental	Base	Total
DR Portfolio	$362,525	$0	$362,525
Total:	$362,525	$0	$362,525

4. Summary of PY2022 Load Impact

The forecasted PY2022 EnergyScout and Fast DR Program load impacts are shown below in Table III-4. The EnergyScout programs will target a lower maintenance level as there is attrition of customers from the respective programs.[5] The Fast DR Program for Hawaiian Electric will target adding 2.722 MW of capacity to replenish the

[5] Order No. 31558 filed in Docket No. 2012-0079 on October 21, 2013, approved the RDLC program to maintain its impact level to end of 2012 by replacing customer attrition. Order No. 31559 filed in Docket No. 2012-0079 on October 21, 2013, approved the CIDLC program to maintain its impact level to end of 2012 by replacing customer attrition.

program to the same level as of the end of 2015. Maui Electric is continuing to work with customers to maintain the enabled load of 4.9 MW and working to find potential new customer enrollment. Customer load impacts have been delayed or reduced due to COVID-19; however, the Fast DR team remains engaged with these customers to maintain enabled load.

Table II-4
Summary of PY2022 EnergyScout and Fast DR Program Load Impacts

Program	Load Impact at Customer Level (MW)
RDLC[1]	13.6
CIDLC[1]	11.1
Fast DR (Hawaiian Electric)[2]	7.0
Fast DR (Maui Electric)[2]	4.9
Total:	36.6

Notes: (1) Impacts were derived using assumptions and methodologies presented in the "2011 EnergyScout Impact Evaluation Report" filed on March 31, 2011 in Docket No. 2007-0341 and is the impact as of October 2019; (2) Fast DR customer level cumulative load impact is the total of the enabled customers.

The forecasted PY2022 DR Portfolio load impacts are shown in Table III-5 below. Enablement under the approved contracts GSPA1 and GSPA2 began in March 2020 and August 2021 respectively. PY2022 forecast assumptions for load impacts for GSPA1 and GSPA2 have been updated to reflect the effects of Force Majeure, as explained in Section III below.

Table II-5
Summary of PY2022 DR Portfolio Grid Services

Grid Services	Grid Services at Customer Level (MW)
Fast Frequency Response (Hawaiian Electric)	15.0
Capacity Load Build (Hawaiian Electric)	6.7
Capacity Load Reduction (Hawaiian Electric)	15.4
Fast Frequency Response (Maui Electric)	1.7
Capacity Load Build (Maui Electric)	1.0
Capacity Load Reduction (Maui Electric)	3.7
Fast Frequency Response (Hawaiʻi Electric Light)	2.2
Capacity Load Build (Hawaiʻi Electric Light)	1.2
Capacity Load Reduction (Hawaiʻi Electric Light)	1.6
Total:	48.5

III. PY2022 CER Operations

A. DR Portfolio

1. Grid Service Implementation with GSPA Aggregators

i. PY2022 Key Activities

The DR Portfolio will be performing the implementation and on-boarding process with aggregators as soon as the contracts are approved by the Commission.[6] Key activities in PY2022 include the following:

- Support ongoing aggregator operations, implementation, on-boarding, and delivery of Grid Services under GSPA1 and GSPA2.
- Work with OATI to exit Force Majeure for GSPA1 and bring delayed resources online.
- Work with OATI to mitigate impacts of Force Majeure on GSPA2 and plan a path forward for on-boarding while continuing to work on implementation activities.
- Select awardees under GSPA3 RFP and begin the implementation and on-boarding process, discussed further in section III.D.2 below.

a. GSPA 1 Aggregator Operations

OATI is the only aggregator delivering Grid Services under GSPA1.

The COVID-19 pandemic has significantly impacted OATI's ability to approach customers for enrollment and gain access to their premises to install the necessary equipment. OATI has modified its marketing efforts to a hyper-local focus and has been successful in enrolling some customers but have not been able to achieve its GSPA1 Contract Capability.[7] As a result, on April 15, 2020 OATI declared Force Majeure for GSPA1. Accordingly, the Companies anticipate filing notice for the extension of OATI's GSPA1 to a new termination date, October 31, 2026.

For PY2022, the Companies will continue to monitor the situation and provide any support required to assist OATI with meeting its Contract Capability for GSPA1. In its most recent update to the Companies, OATI stated that they expect the Force Majeure event to end on November 30, 2021. OATI also provided an updated Exhibit H. The updated Exhibit H shows residential resources to start ramping in Q4 2021 and be fully enabled in Q2 2022. It also shows commercial resources to start ramping in Q3 2022 and be fully enabled in Q4 2022. Table III-7 includes the updated capability targets for GSPA1.

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[6] See Docket No. Docket No. 2007-0341 DSM Adjustment filed July 9, 2020, requesting approval for cost recovery for the executed GSPA contracts negotiated in RFP No. 103119-02 ("GSPA2").
[7] See Docket No. 2007-0341, Order No. 36467 filed August 9, 2019.

b. <u>GSPA 2 Aggregator Operations</u>

OATI and Swell are the aggregators delivering Grid Services under GSPA2.

On August 24, 2021, OATI declared Force Majeure for GSPA2 stating *"The conditions created by the COVID-19 pandemic have, and will continue to have, significant impact on OATI's ability to perform under the GSPA."*

OATI also stated *"many of the behind-the-meter projects that were committed to participate in the program have been put on hold or altered as a direct result of the pandemic. OATI and our Alliance Members are taking the steps possible to mitigate the effect of the COVID- 19 event. OATI continues to operate the GSDS, and the OATI project team is interacting regularly with its Company counterparts. OATI is actively working with our Alliance Members to find assets to provide grid services and commence integration with their systems into the GSDS. However, the nature of the COVID-19 event – quarantine, social distancing, supply chain delays, etc. – has rendered it impossible for OATI and its Alliance Members to continue as previously expected or anticipated to deliver the committed grid services as scheduled. Further, at this point we cannot predict when the enablement will return to pre-COVID-19 event levels."*

In an update to the Companies on October 13, 2021, OATI stated that COVID-19 caused the loss of all commercial and residential resources for GSPA2. OATI has found a replacement for 1MW of the contracted 1.25MW capacity reduction resource from commercial sites and expects to have it online in Q4 of 2022. OATI is continuing to look for additional load to fulfill the entire contract capability for commercial resources. For residential capacity reduction resources, OATI is looking for replacements for these sites. At the time of this filing, OATI does not yet have an updated enablement schedule. At this time, Hawaiian Electric estimates that ramping will begin in Q3 2022.

In the same update, OATI informed the Companies that *"through in-depth study of the FFR1 specification and extensive discussions with technology providers it has become evident that FFR1 as a grid service from customer-sited resources is not achievable under the existing requirements as specified by Hawaiian Electric. Accordingly, OATI has no alternative but to exercise its right under Section 7.3(a) of the GSPA2 contract to update its Contract Capability by reducing the FFR1 grid service to zero."*

Hawaiian Electric has requested an updated Exhibit H for OATI's GSPA2 contract and upon receipt will update the Commission via Dkt No. 2007-0341.

Swell is expected to start delivering Grid Services in late 2021 and continue to enroll customers throughout PY2022 and PY2023. Integration of Swell's Grid Services Delivery Systems ("GSDS") has been delayed from June 6, 2021 to Decembver 22, 2021. In accordance with Artcile 1 of the GSPA, the Companies and Swell agreed to delay system integration due to limited availability of the DRMS test and production systems resulting from the DRMS upgrade activities and schedule. In addition, Swell has also experienced delays in receiving FFR certification from subcontractors.

Swell has also raised concerns about acquiring new customers under GSPA2 as a result of the SDP ("Battery Bonus") launch. Swell's proposal under GSPA2 did not include an enablement fee because early enrollment results indicated that the lack of upfront incentives for participants has put Swell at a disadvantage in the market. Hawaiian Electric is awaiting qualitative and quantitative data from Swell supporting these concerns. Hawaiian Electric and Swell have also been discussing potential changes to GSPA2 (for Oʻahu only) to bolster Swell's attractiveness in the market. Provided the data supports any GSPA2 modifications, the Company would likely request approval for cost recovery of Swell's amended GSPA2.

ii. PY2022 Program Budget and Load Impacts

Table III-6 and Table III-7 below provide the projected DR Portfolio budgets for Hawaiian Electric, Maui Electric, and Hawaiʻi Electric Light, respectively.[8] Table III-3 shows the forecasted load amount that will be delivered by the aggregators.

Table III-6
DR Portfolio
2022 Budget ($)

	Incremental	Base	Total
DR Portfolio (Hawaiian Electric)	$5,837,647	$0	$5,837,647
DR Portfolio (Maui Electric)	$1,497,288	$0	$1,497,288
DR Portfolio (Hawaiʻi Electric Light)	$362,525	$0	$362,525
Total:	$7,697,460	$0	$7,697,460

[8] See Docket No. 2007-0341, Decision and Order No. 36467 filed on August 9, 2019, approving the GSPA contract with OATI, and its related DR Portfolio Variable Costs to be recovered through the DSM Surcharge.

Table III-7
DR Portfolio
2022 Program Impact (MW)

	Program	Grid Services at Customer Level (MW)	Grid Services By Island (MW)
DR Portfolio (Hawaiian Electric)	Fast Frequency Response	15.0	37.1
	Capacity Load Build	6.7	
	Capacity Load Reduction	15.4	
DR Portfolio (Maui Electric)	Fast Frequency Response	1.7	6.4
	Capacity Load Build	1.0	
	Capacity Load Reduction	3.7	
DR Portfolio (Hawaiʻi Electric Light)	Fast Frequency Response	2.2	5.0
	Capacity Load Build	1.2	
	Capacity Load Reduction	1.6	
	Total:	48.5	48.5

The Contracted Capability targets in Table III-7 have been updated to reflect the effects of Force Majeure on OATI GSPAs, as well as the delayed onboarding of Swell.

GSPA 3 Capability is still being evaluated in RFP-101321-01 and is not included in the tables above.

B. Programs

1. Residential Direct Load Control Program

Hawaiian Electric will continue the existing CER Operations to maintain customer participation and MW impacts for RDLC. Order No. 32660, issued by the Commission in the subject proceeding on February 2, 2015, clarified that the existing programs may continue at current maintenance levels without modification until a further order is issued.[9]

i. PY2022 Key Activities

In 2022, Hawaiian Electric will engage in the following key activities in support of the RDLC Program:

- Maintain existing RDLC Program infrastructure to continue providing FFR and allow Hawaiian Electric's System Operations to dispatch DR resources during peak load and economically favorable conditions. Third-party program implementers will continue to provide program maintenance by supporting customers and field installations.
- Issue an RFP to replace exiting RDLC hardware and infrastructure, see Section III.D.1.

[9] Docket No. 2007-0341, Order No. 32660, filed on February 2, 2015, at 12.

ii. PY2022 Program Budget and Demand Savings Impacts

For the PY2022, as shown in Table III-7 below, Hawaiian Electric will include all RDLC program costs in base rates in accordance with the Hawaiian Electric 2017 test year rate case. As of 2022, the impact for the RDLC Program is 13.6 MW (customer level). See Exhibit A for additional details.

Table III-7
Hawaiian Electric RDLC Program
2022 Program Budget ($)

RDLC Program	2022 Program Budget
Incremental	$0
Base	$1,788,840
Total:	$1,788,840

2. Commercial and Industrial Direct Load Control Program

Hawaiian Electric will continue the existing CER Operations to maintain customer participation and MW impacts for CIDLC. Order No. 32660, issued by the Commission in the subject proceeding on February 2, 2015, clarified that the existing programs may continue at current maintenance levels without modification until a further order is issued.[10]

i. PY2022 Key Activities

In 2022, Hawaiian Electric will engage in the following key activities in support of the CIDLC program:

- Maintain existing CIDLC program infrastructure to continue providing FFR and allow Hawaiian Electric's System Operations to dispatch DR resources during capacity shortfall conditions. Third-party program implementers will continue to provide program maintenance by supporting customers' field installations.
- Perform customer survey to determine and encourage participant operational readiness, including potentially transitioning large commercial participants to Open Automated DR ("OpenADR").

ii. PY2022 Program Budget and Demand Savings Impacts

As shown in Table III-8 below, Hawaiian Electric will include all CIDLC program costs in base rates in accordance with the Hawaiian Electric 2017 test year rate case. As of 2021, the target impact for the CIDLC program is 11.1 MW (customer level). See Exhibit A for additional details.

[10] Order No. 31559 filed in Docket No. 2012-0079 on October 21, 2013, approved the CIDLC program to maintain its impact level to end of 2012 by replacing customer attrition.

Table III-8
Hawaiian Electric CIDLC Program
2022 Program Budget ($)

CIDLC Program	Existing Year 2022 Budget
Incremental	$0
Base	$2,494,000
Total:	$2,494,000

3. Fast DR Program

i. PY2022 Key Activities

In 2022, Hawaiian Electric and Maui Electric will engage in the following key activities in support of the Fast DR Program:

- Maintain existing Fast DR Program infrastructure to allow Hawaiian Electric and Maui Electric System Operation to dispatch DR resources during peak load and economically favorable conditions. Third-party program implementers will continue to provide program maintenance by assisting in responding to service calls and supporting field installations.
- Hawaiian Electric will seek 2.722 MW of capacity to replenish the program.
- Hawaiian Electric will work with participants whose performance has been affected by COVID.

In accordance with Hawaiian Electric's Emergency Demand Response Program Implementation Plan and D&O 37853, Hawaiian Electric will target customers from the military, hospitality, commerce, and condominium sectors to add 2.722 MW of capacity and reach its 7 MW program capacity. Hawaiian Electric is aware of participants who have been negatively affected by COVID and will seek solutions to improve their performance.

ii. PY2022 Program Budget and Demand Savings Impacts

Table III-10 and Table III-11 below provide the Fast DR Program budgets for Hawaiian Electric and Maui Electric, respectively. The targeted 2022 impact for the Fast DR Program is 7.0 MW (customer level) for Hawaiian Electric and 4.9 MW (customer level) for Maui Electric. See Exhibit A for additional details.

Table III-10
Hawaiian Electric Fast DR Program
2022 Program Budget ($)

Fast DR Program (Hawaiian Electric)	2022 Program Budget
Incremental	$0
Base	$440,000
Total:	$440,000

Table III-11
Maui Electric Fast DR Program
2022 Program Budget ($)

Fast DR Program (Maui Electric)	2022 Program Budget
Incremental	$0
Base	$408,000
Total:	$408,000

C. CER Operations Technology

Implementation of high availability infrastructure for the DRMS will be completed during summer of 2022. High availability infrastructure will provide additional redundancy and resiliency that will be built into the DRMS infrastructure by adding servers and redundant applications and processes to minimize system downtime. Integration with the Meter Data Management System for meter interval data will also be performed in PY2022.

Ongoing maintenance activities will continue and include implementing security patches, application updates from the DRMS vendor, and additional reporting and tracking as needed for monitoring performance of programs and aggregators. Control technology for existing EnergyScout programs will also continue to be maintained, including implementing security patches and application updates from the Yukon vendor.

In accordance with Hawaiian Electric's Emergency Demand Response Program Implementation Plan and D&O 37853, the Companies are adding capability to the Hawaiian Electric O‘ahu DERMS to pay Battery Bonus incentives, by utilizing current incentive processes with SAP. Phase 1 of this integration will be complete by the end of

2021, but additional phases to add the other two incentive tiers will not occur until early 2022.

The Companies plan to fully transition to IEEE 1547-2018 for all new DERs on April 1, 2022. The IEEE 1547-2018 standard requires all DER to provide a communication interface that may allow for point-to-point telemetry and complex operational controls using a standard communication protocol. The Companies will scale integration of 1547-2018 inverters using the IEEE 2030.5 platform contracted in PY2021, with a level of DRMS integration no more than six months after the IEEE 2030.5 platform enters production use. The Companies will also continue assessing options and cost for extending the existing OpenADR implementation to accommodate complex controls for direct-to-device point-to-point communications.

D. CER Operations Initiatives

1. RDLC Transition RFP

As discussed in the Companies' 2020 M&E Report[11] and 2021 A&S Report,[12] the Companies are pursuing a programmatic solution to transition the existing EnergyScout Program participants to a new program(s) that offers grid service delivery. Specifically, existing EnergyScout Program participants would be able to deliver a variety of grid services by relying on smarter, two-way communicating devices/equipment.[13] While there are still many unknowns, the Companies believe that this solution would also be a participation option under a Bring Your Own Device ("BYOD") program.[14]

To this end, the Companies anticipate issuing an RFP at the end of 2021 seeking a DLC device that would control electric water heaters to replace the existing RDLC Load Control Receivers ("LCR"), a head system to control and aggregate the fleet of water heaters, price for installing these devices, and an administrator that would enable and monitor the replacement of the existing devices and provide ongoing program maintenance. The RFP also included a request for a DLC device to control residential and small business central A/C and/or split A/C systems from the same supplier of DLC devices for water heaters. If the RFP results in costs that are not feasible for a smooth transition, the Companies will also consider transitioning resources to an aggregator.

The Companies plan to discuss opportunities to collaborate with Hawaii Energy for rebates to add more value to customers.

[11] See Docket No. 2007-0341, the Companies' Annual Program Modification and Evaluation Report filed November 25, 2020 ("2020 M&E Report") at 12-14.
[12] See Docket No. 2007-0341, the Companies' Annual Program Accomplishments and Surcharge Report (" Report filed March 31, 2021 ("2021 A&S Report") at 15-16.
[13] Transitioning large commercial customer to new infrastructure is discussed in Section III.B.2.
[14] See Docket No. 2017-0323, Hawaiian Electric's DER Program Track Final Proposal, filed May 3, 2021at 23-28.

2. Grid Services From Customer-Sited Distributed Energy Resources – Island of O'ahu RFP

On August 16, 2021 the Company released RFP-101321-01 (GSPA3 RFP). The RFP is intended to acquire Grid Services as a consequence of the planned retirement of the Hawai'i generating facility located in Kalaeloa ("AES"). O'ahu's Energy Reserve Margin capacity planning criteria indicates there is a risk of a capacity reserve shortfall upon expiration of the AES Purchase Power Agreement if, among other things, commercial operation of the RFP Stage 1 solar plus storage projects and the RFP Stage 2 Kapolei Energy Storage are delayed. The GSPA3 RFP seeks Grid Services on O'ahu only, targeting 60 MW of Capacity Reduction, however Proposers are able to bundle grid services with Capacity Build (up to 60 MW) and/or FFR-2 (up to 12 MW). The Company is currently negotiating GSPAs with bidders selected for award under GSPA3 RFP and anticipates submitting a request for cost recovery of the selected GSPA(s) in the first quarter of 2022.

3. Rooftop Rental

Earlier this year, the Company began the Rooftop Rental Initial Assessment to demonstrate interest and feasibility for a cost-effective Rooftop Rental Program, on O'ahu. The Company issued a RFP and contacted various customer segments to implement this program. However, after completing a cost analysis and having difficulty obtaining the number of customers needed, the Company will delay the Initial Assessment until PY2022 and will not submit a Rooftop Rental program application to the Commission in early 2022. For PY2022, the Company will propose the Rooftop Rental Initial Assessment as a pilot project through the Pilot Process.[15]

E. Evaluation, Measurement & Verification (EM&V)

On February 10, 2017, in the Revised DR Portfolio filing, the Companies requested a three-year EM&V cycle, and in Decision and Order No. 35238,[16] the Commission found that "the proposed reporting structure is reasonable and provides sufficient transparency and timely updates to inform the relative success of the DR program." In the 2019 A&S report,[17] Cadmus (the Companies' EM&V consultant) provided a memo depicting how benefits will be realized with the use of aggregator performance data. In the 2020 M&E report, Cadmus provided findings on OATI's processes including areas of DRMS integration, forecasting grid services capability and settlements, marketing and enrollment of Hawaiian Electric customers, customer satisfaction, and evaluation.

[15] See Docket No. 2018-0088, Decision and Order 37507, issued December 23, 2020.
[16] See Docket No. 2015-0412, Decision and Order 35238, issued on January 25, 2018, at 83.,
[17] See Docket No. 2007-0341, the Companies Annual Program Accomplishments and Surcharge Report ("2019 A&S Report"), filed on March 29, 2019, Exhibit G.

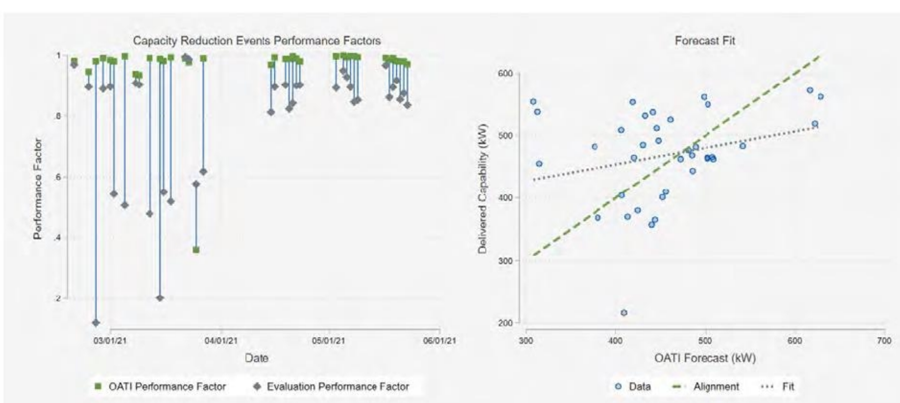
In 2021, Cadmus analyzed OATI's water heater performance by comparing test data to forecast for Capacity Build, Capacity Reduction, and FFR events. In summary, OATI performed better over the four month test period and was able to provide accurate results as compared to its forecast, as shown in the graph below. Cadmus also analyzed the Company's settlement 10/10 baseline calculation used in the GSPA, and found that the baseline performs well on the average pseudo-event[18] day. Cadmus installed seven data loggers at OATI customer locations to verify that data provided by OATI is accurate. The correlation coefficient between Cadmus data loggers and OATI telemetry data across all water heaters was 0.999 with a mean absolute percent error of 3.1%. A report describing Cadmus's findings is provided as Exhibit B to this report.

Cadmus determined that under GSPA1, EM&V results show that Grid Services are being delivered within the requirements of the contract. While Grid Services contracted under GSPA1 are relatively small, the evaluation team noted that two items could become issues if the aggregated resource under GSPA1 were expanded:

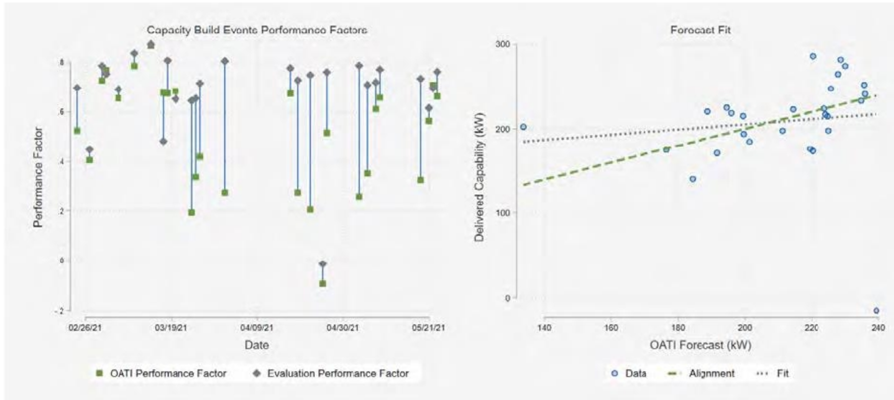
- Water heater consumption after Capacity Reduction events was high compared to pre-event consumption and should be constrained by GSPA1 Capacity Ramp Rate requirements.
- Capacity Build events did not show a consistent, sustained increase in load but showed a relatively volatile (i.e. spiky) Grid Service delivery during the event. For GSPA1, Capacity Build performance is assessed using a 1 hour interval which obscures in-hour volatility. For subsequent GSPAs, performance assessment is measured on 15 minute intervals to encourage a consistent response during Capacity Build events.

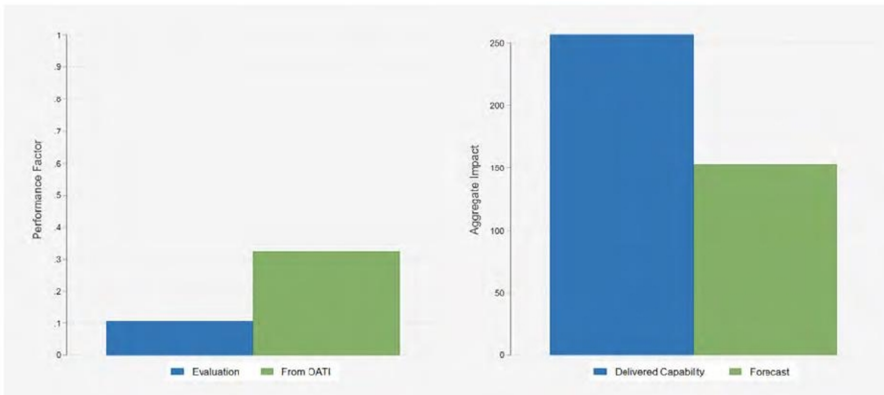
The Companies will continue to monitor Ramp Rate and event performance and implement or modify the Grid Service requirements as needed to ensure their desired operation.

Figure 1:Capacity Reduction, Capacity Build and Fast Frequency Response Events Performance Factors and Forecast



[18] A "pseudo-event" day is a non-event days similar to events but where no event was actually called





i. <u>PY2022 Key Activities</u>

The 2022 evaluation tasks include the following:

- Estimate the DR impacts for FFR, Capacity Build, and Capacity Reduction by end use on O‘ahu for batteries and commercial customers.
- Collect data loggers deployed on residential water heaters at the conclusion of the water heater impact analysis and reconfigure for deployment with batteries/PV systems.
- Evaluate settlement process for its accuracy.
- Evaluate forecasts submitted by aggregator for accuracy.

IV. Conclusion

In conclusion, the Companies respectfully submit this M&E Report which details the required activities and budget to maintain the existing CER Operations, expands the implementation of the DR Portfolio in 2022, and plans for pursuing a programmatic solution to transition the existing EnergyScout participants to a new program(s) that offers multiple grid service delivery.

EXHIBIT A
Existing Legacy DR Programs
2022 Budget ($)

	RDLC Program[2]	CIDLC Program[2]	Fast DR (Hawaiian Electric)[2]	Fast DR (Maui Electric)[2]
Incremental[1]				
Incentives	0	0	0	0
Materials				
Equipment Purchases	0	0	0	0
Outside Services				
General	0	0	0	0
Installation Allowance	0	0	0	0
Advertising and Marketing	0	0	0	0
Evaluation	0	0	0	0
Miscellaneous	0	0	0	0
Subtotal	0	0	0	0
Other				
Travel	0	0	0	0
Amortization	0	0	0	0
Software-Maintenance	0	0	0	0
Miscellaneous	0	0	0	0
Subtotal	0	0	0	0
Base[2]				
Incentives	1,308,000	2,194,000	240,000	384,000
Materials				
Equipment Purchases	0	0	0	0
Transportation				
Vehicles	0	0	0	0
Outside Services				
General	480,840	300,000	200,000	24,000
Installation Allowance	0	0	0	0
Advertising and Marketing	0	0	0	0
Evaluation	0	0	0	0
Miscellaneous	0	0	0	0
Subtotal	480,840	300,000	200,000	24,000
Other				
Travel	0	0	0	0
Amortization	0	0	0	0
Software-Maintenance	0	0	0	0
Miscellaneous	0	0	0	0
Subtotal	0	0	0	0
Total Program Cost	**1,788,840**	**2,494,000**	**440,000**	**408,000**
Total Incremental Cost	0	0	0	0
Total Base Cost	1,788,840	2,494,000	440,000	408,000

NOTES:
[1] Incremental expenses are recovered through the IRP Cost Recovery Adjustment.
[2] Base expenses are recovered through base rates and not the IRP Cost Recovery Adjustment.

EXHIBIT A
DR Portfolio & Implementation Phase
2022 Budget ($)

	DR Portfolio (Hawaiian Electric)	DR Portfolio (Maui Electric)	DR Portfolio (Hawaii Island)	DRMS Amortization & M&S[3]	DRMS[2]
Incremental[1]					
Incentives	1,298,123	376,471	287,279	0	0
Materials					
Equipment Purchases	0	0	0	0	0
Outside Services					
General	4,539,525	1,120,817	75,246	0	0
Installation Allowance	0	0	0	0	0
Advertising and Marketing	0	0	0	0	0
Evaluation	0	0	0	0	0
Miscellaneous	0	0	0	0	0
Subtotal	4,539,525	1,120,817	75,246	0	0
Other					
Travel	0	0	0	0	0
Amortization	0	0	0	324,379	0
Software-Maintenance	0	0	0	383,217	0
Miscellaneous	0	0	0	0	0
Subtotal	0	0	0	707,596	0
Base[2]					
Incentives	0	0	0	0	0
Materials					
Equipment Purchases	0	0	0	0	0
Transportation					
Vehicles	0	0	0	0	0
Outside Services					
General	0	0	0	0	0
Installation Allowance	0	0	0	0	0
Advertising and Marketing	0	0	0	0	0
Evaluation	0	0	0	0	0
Miscellaneous	0	0	0	0	0
Subtotal	0	0	0	0	0
Other					
Travel	0	0	0	0	0
Amortization	0	0	0	0	0
Maintenance and Support	0	0	0	0	160,000
Miscellaneous	0	0	0	0	0
Subtotal	0	0		0	160,000
Total Program Cost	**5,837,647**	**1,497,288**	**362,525**	**707,596**	**160,000**
Total Incremental Cost	5,837,647	1,497,288	362,525	707,596	0
Total Base Cost	0	0	0	0	160,000

NOTES:
[1] Incremental expenses are recovered through the IRP Cost Recovery Adjustment.
[2] Base expenses are recovered through base rates and not the IRP Cost Recovery Adjustment.
[3] The above amounts are reflective of filings under Docket 2015-0411. These incremental expenses will be recovered through the Renewable Energy Infrastructure Cost Recovery Provision.

CADMUS

GSPA #1 Evaluation Report

November 17, 2021

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List of Acronyms

AC	Alternating current
AMI	Advanced metering infrastructure
DERMS	Demand response management system
FFR	Fast-frequency response
GIWH	Grid-interactive water heaters
GSPA	Grid Services Purchase Agreement
HECO	Hawaiian Electric Company
OATI	Open Access Technology International
OLS	Ordinary least squares
PV	Photovoltaic
RCT	Randomized controlled trial

Executive Summary

This report presents results from the evaluation of demand response grid services provided by residential grid-interactive water heaters in 2021 to Hawaiian Electric Company (HECO) through the Grid Services Purchase Agreement (GSPA) #1. The contract between HECO and Open Access Technology International (OATI), a third-party aggregator, provides for the delivery of fast-frequency response (FFR), capacity build, and capacity reduction demand response grid services on Maui and Oʻahu. Shifted Energy, an OATI subcontractor, retrofitted residential electric resistance water heaters with its own Tempo smart controller devices to implement this part of the GSPA. HECO contracted with Cadmus and Demand Side Analytics to evaluate the performance of GSPA #1 on Oʻahu by measuring demand impacts and verifying the accuracy of OATI's settlement calculations, settlement methods, and grid services forecasts. Cadmus used a randomized controlled trial (RCT), the gold standard in evaluation, to estimate the grid services impacts. The RCT study took place between January 21, 2021, and June 1, 2021, during which time HECO called 27 capacity build events and 37 capacity reduction events, and one FFR event was triggered.

Conclusions

The following are conclusions and supporting findings from the GSPA #1 evaluation.

Telemetry Data Accuracy

The GSPA water heater telemetry data accurately measure water heater electricity demand at 5-minute intervals, validating the use of these data for impact evaluation. OATI uses water heater telemetry data to calculate settlement performance and forecasts, and the evaluation team also used these data in the impact evaluation as AMI data were unavailable. To validate OATI telemetry readings of electricity demand, the evaluation team installed data loggers on GSPA water heaters. Across a 20-day comparison period (May 12 to May 31, 2021) covering a sample of seven water heaters, the implementer's 5-minute telemetry data and the evaluation team's logger data aggregated to 5-minute intervals were very highly correlated (correlation coefficient = 0.999), the mean absolute percentage error observed between the two data sources was low (3.1%), and the average difference per interval between the recorded demand values was less than three watts.

Capacity Build

In general, capacity build events greatly increased water heater electricity demand relative to baseline demand. On average, electricity demand increased by 0.159 kW per water heater, or 76% relative to the reference load. Many capacity build events increased demand by more than 90%. Except for one event (April 25, 2021), all capacity build events increased water heater demand by 40% or more.

Capacity Reduction

During most capacity reduction events, water heating electricity demand was reduced to nearly zero, showing that most water heaters that would have been operating remained off. On average, electricity demand was reduced by an average of 0.321 kW per water heater, or 95% of the reference load across all events. All but one event (March 25, 2021) reduced demand by 93% or more. Nine of the events reduced demand by 100%.

After capacity reduction events, electricity demand significantly increased by up to 1 kW per water heater. Across all events, demand increased by an average of 0.5 to 0.6 kW per water heater (more than 160% of the reference load) in the half hour following the capacity reduction event. This higher-than-normal demand (snapback) lasted for at least 45 minutes after the events.

Fast Frequency Response

FFR decreased water heating electricity demand in response to detection of an underfrequency event. The one FFR event during the study period achieved nearly a 100% reduction in demand (0.107 kW per water heater, a 96% reduction). However, it was not possible to verify the FFR response time due to the discrepancy between the interval length of the kW telemetry data (five-minutes) and the short duration of the FFR event.

Settlement Verification

While the evaluated and OATI-reported event performance factors did not match, the reported performance was not systematically higher than what was found in this analysis. Event performance factors measure how closely the load impacts, measured using baselines, align with the forecasted capacity. They form the basis for settlement payments to the vendor. In general, the evaluated performance factors were higher than those reported by OATI for capacity build events and lower for capacity reduction events. In both the evaluator's analysis and in the reported OATI results, performance factors for capacity reduction events were generally higher than those for capacity build. The source of the discrepancy between the calculated results and those reported by OATI was not determined, but in practice could have been due to different versions of the forecast data or event timestamps, or inconsistent application of the baseline methods. The Cadmus team found that the capacity reduction settlement performance factors calculated as part of this evaluation more closely aligned with those reported by OATI in the later months of the evaluation period – April, May, and June – while no clear trend could be discerned for capacity build events.

Settlement Accuracy

The baseline calculation methods prescribed in the GSPA are sufficiently accurate for the measurement of grid service impacts. GSPA Capacity uses a 10-in-10 similar day baseline method, while the FFR event uses demand in the interval before the event. The magnitude of bias associated with each baseline is less than ±5% for all three grid services. As the *ex post* load impacts calculated by the evaluation team were approximately 76% of baseline demand for capacity build, 95% of baseline demand for capacity reduction, and at least 28% of baseline demand for FFR,[1] the magnitude of the bias associated with the baseline methods was substantially lower than the magnitude of the reductions

[1] This result is based on the first interval of the event.

delivered in the events themselves. As a result, the evaluation team finds no need to recommend changes to the GSPA-prescribed baseline method of the baseline algorithms.

Forecast Accuracy

The forecasts for capacity build and capacity reduction events improved slightly over the course of the evaluation, driven by improvements in accuracy for each 15-minute period of the events. In general, forecasts for capacity reduction improved more than those for capacity build. The overall forecast accuracy for capacity build and reduce events was -22.0% and –17.6%, respectively. This means that the forecast tended to understate the load reductions compared to the *ex post* results by slightly more than 17-20%.The FFR forecast error compared to the *ex post* results was 16.3%, meaning that the forecast was more than 16% higher than the *ex post* results. The under-performance of the water heaters relative to the ex post impacts during the FFR event was due to the small response seen in the first interval of the event, from 4:45AM to 4:50AM. In the second interval of the event, from 4:50AM, the Cadmus team found that the *ex post* reduction was approximately 30% higher than the forecast. As there was only one event for FFR, no trends could be established and it was not possible to evaluate the accuracy of FFR forecasts conclusively.

Recommendations

The evalution team offers the following recommendations to HECO to improve performance of grid services, accuracy of the settlements, and accuracy of the grid services forecasts.

HECO grid operators should prepare for significant snapback in electricity demand immediately after capacity reduction events. If HECO scales the water heater demand response program and snapback is not managed, there may be large increases in electricity demand on HECO's system. Grid planners should keep this snapback in mind when calling upon enrolled water heaters for capacity reduction grid services. If the snapback evaluated here is of concern to HECO planners, future GSPAs could modify the requirements in the GSPA #1 concerning the maximum allowable increase in demand following capacity reduction events.[2]

Higher frequency electricity demand data and a larger number of events should be used to evaluate FFR more conclusively. To assess the FFR response time to frequency events, future evaluations should collect demand data at higher frequencies than 5 minutes. In addition, as there was only one FFR event during the RCT study period, the evaluation was unable to evaluate the FFR performance across multiple events. In the future, HECO should extend the evaluation timeframe to include a larger number of FFR events.

HECO should continue working with the GSPA aggregators to improve the quality of data provided to evaluators and to streamline the data transfer process. The evaluation team encountered issues with

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[2] The GSPA #1 currently specificies that capacity resources must return to normal operating state at no more than 10% of total forecasted capability per minute until an aggregate of 50 MW is enrolled, and up to 2 MW per minute when more than 50 MW is enrolled.

data ranging from inconsistencies between data sets in the time stamp definitions (interval beginning vs. endings) and potential version control issues for grid services forecasts to delays in providing data. In the end, most issues were resolved, but they slowed the evaluation and the process for collecting and transferring data could be improved.

Forecast files should be documented with their version and creation date(s). Because the GSPA requires regular and frequent updates of the grid service forecasts to be made available to HECO, proper version control should be maintained when sending the month-end settlement and forecast files to HECO. The forecast against which performance factors should be constructed are the most recent forecast prior to the vendor being notified of a scheduled event. Adding a forecast creation timestamp to the forecast files at the end of the month will improve the ability of HECO and third parties to reconstruct event performance factors in settlement.

Required monthly invoice documentation should be amended to include supplemental data for assessing settlement performance factors. This study found discrepancies between vendor-reported and evaluator-calculated performance factors for all three grid services. As noted in the study conclusions, while these discrepancies did not show a consistent trend in over or under-reporting of event performance, the root cause may be due to lack of transparency in source data files. Amending the GSPA to require supplemental data, including information about the baseline days used to construct the reference load for each event and aggregate participant 5-minute loads on each baseline day, would allow HECO to replicate settlement performance factors on a regular basis. This should result in more rapid identification of discrepancies in data, assumptions, or calculations.

Vendors should rely on estimates of delivered capability from prior events to improve forecast accuracy. If the vendor is not yet using the estimates of delivered capability from past events as an input in to forecast model fine-tuning, they should begin to do so. This study found that the settlement methods prescribed by the GSPA are accurate and precise enough to capture the true load impacts of each event, so using these estimates will continue to improve forecast accuracy and event performance factors over time. The way in which event performance factors are defined in the GSPA already provide a strong incentive to vendors to improve forecasts over time.

Future GSPAs should add performance requirements to maintain or enhance grid stability during capacity events. As noted above, GSPA #1 includes requirements about the permissable amount of snapback of electricity demand after capacity events end. In future GSPAs, HECO should consider adding requirements about the maximum permissible ramping of loads up or down during capacity events. This will help to ensure that the delivery of grid services is consistent during events and does not destabilize the grid.

Introduction

With a clean energy goal of 100% electricity sales from renewable sources by 2045, Hawai'i is increasing its reliance on utility-scale wind and solar power. In 2020, Hawaiian Electric Company (HECO), a vertically integrated utility providing electricity service on five islands and to 95% of the state's residential customers, generated 35% of its electricity from renewables.[3] To meet the 2045 clean energy goal, HECO will need to find new ways of balancing its grid and addressing issues related to intermittency, the over-and under-supply of power, and ramping from integrating renewable resources. Specifically, HECO is looking for alternative sources of grid services currently provided by diesel generating facilities and is investing in utility-scale battery storage and distributed energy resources (DERs), including grid-interactive water heaters and behind-the-meter batteries with solar photovoltaic (PV).

In this report, the GSPA evaluator (Cadmus and Demand Side Analytics, henceforth, the Cadmus team) presents results from the evaluation of demand response grid services provided by residential grid-interactive water heaters (GIWHs) in 2021 to HECO through the Grid Services Purchase Agreement (GSPA) #1. The contract between HECO and OATI, a third-party aggregator, provides for the delivery of fast-frequency response (FFR), capacity building, and capacity reduction demand response grid services on Maui and O'ahu.

Grid Services Purchase Agreement #1

In March 2019, Hawaiian Electric reached agreement with OATI to provide 11 MW of FFR, 1 MW of capacity build, and 10 MW of capacity reduction demand response capacity between 2019 and 2024.[4] The demand response capacity would be provided by a mix of residential GIWHs, residential solar PV and battery storage systems, and commercial battery storage systems on the islands of O'ahu and Maui.

Implementation of the grid services contract was delayed by about one year because the COVID-19 pandemic slowed down participant recruitment and integration of OATI's and HECO's demand response management systems took longer than expected. As a result, only grid services from residential GIWHs on O'ahu were operational in 2020 and 2021. Shifted Energy, an OATI subcontractor, implemented this part of the GSPA.

Beginning in January 2020, Shifted Energy began enrolling residential customers in water heater demand response. Most GIWHs participating in the GSPA were in low- or middle-income multifamily residential buildings. Shifted Energy targeted multifamily buildings because, in most cases, it was possible to coordinate with a single building manager rather than individual customers and it was

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3 Hawaiian Electric. Accessed November 7, 2021. "Clean Energy Hawaii." https://www.hawaiianelectric.com/clean-energy-hawaii.

4 Public Utilities Commission of the State of Hawaii (August 9, 2019). Order No. 36467 Approving the HECO Companies' Grid Services Purchase Agreement with Open Access Technology International. https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A19H12A85058F00420

possible to economize on installation costs by installing multiple controllers at one site. Shifted Energy also enrolled a small number of water heaters in single-family homes.

Shifted Energy retrofitted residential electric resistance water heaters at participating facilities with Tempo smart controllers, which respond instantly to commands to turn the units on or off from OATI's Grid Services Delivery System or automatically when the water heaters detect a deviation from the desired frequency (i.e., over- or under- frequency event) on HECO's electric distribution system. As water heaters are relatively well insulated, they can store energy, analogous to batteries, and help utilities to absorb energy during periods of excess power supply. The oversupply of power on HECO's system is a frequent occurrence because of growing integration of renewable energy resources. The controllers communicate with the implementer control system through a cellular network connection, avoiding the need to rely on the residential customer's Wi-Fi network.[5] The controller's current transformer collects high-frequency voltage, current, and frequency measurements.

GIWHs enrolled in the GSPA provided the following grid services:

- **Capacity Build**. On event days between 10:00 am and 2:00 p.m. (the system's midday renewable generation peak), the water heaters run more than usual to absorb solar generation off the grid. Capacity build events are active for the entirety of the four-hour period.
- **Capacity Reduction**. On event days between 5:00 and 9:00 p.m. (the system's evening peak demand period), the water heaters run less than usual to reduce overall demand, deferring this demand until later in the evening. Capacity reduction event length is variable up to four hours, and HECO determines each event's length.
- **FFR.** Per the GSPA, FFR is a local discrete response at a specified frequency trigger (as opposed to capacity build and reduce events, which are scheduled and deployed remotely from HECO's distributed energy resource management system [DERMS].) Each device continuously measures the frequency of the alternating current (AC) at its location. When the frequency drops below the frequency trigger (defined as 59.7 Hz in GSPA #1), the devices shut off the water heaters within 12 AC cycles. The GSPA permits for a frequency measurement deviation of ±0.02 Hz in this requirement. Once the devices detect that the grid AC frequency has returned to normal (60 Hz or more), the devices allow the water heaters to turn on again. The devices are allowed to turn back on sequentially, with groups of no more than 10% of the enrolled devices coming back on per minute. FFR events can occur on any day at any time.

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[5] Shifted Energy's Tempo controllers are wired upstream of the water heater. Unlike other GIWH implementations, Shifted Energy's controllers do not directly measure tank temperature, increase the existing water temperature set point, or require any modifications to plumbing (such as temperature mixing valves.) As a result, Shifted Energy's controllers cannot force a water heater to turn on if the water heater has already met its set point; thus, energy storage is achieved through strategically deferring water heating demand (by shutting the water heater off) so that it can absorb excess renewable generation later.

Operational Forecasts and Settlements

Per the requirements of the GSPA, the aggregator provides HECO with operational forecasts for each grid service at regular frequencies. The forecasts are generated with the water heater voltage, current, and frequency measurements. [6] Table 1 shows the attributes of each forecast that the aggregator transmits from its grid services delivery system to HECO's DERMS.

Table 1. Operational Forecast Attributes

Attributes	Aggregator Grid Services		
	FFR	Capacity Building	Capacity Reduction
Forecast Capability	kW/kWh	kW/kWh	kW/kWh
Forecast Term (minimum)	4 days	4 days	4 days
Data Resolution (interval)	15-minutes	15-minutes	15-minutes
Update Timing	Hourly	1 a.m./1 p.m.	1 a.m./1 p.m.
Update Frequency	Hourly	Every 12 hours	Every 12 hours

In addition to providing grid services forecasts, the GSPA aggregator is required to submit monthly settlement reports (called monthly invoice report, or MIR) to HECO for use in verifying the supply of grid services and paying the aggregator. Each MIR includes numerous data for settlement, including the DERMS forecasts, event performance factors, settlement factors, baseline calculations, and end-use data. The aggregator is compensated based on the event performance factor, which measures the average deviation in performance between the forecasted demand response capability and the delivered capability. Per the GSPA, the delivered capability for capacity build and capacity reduction demand response is calculated with 5-minute interval telemetry data and a 10-in-10 similar day baseline.[7] Delivered capability for FFR is estimated by comparing electricity demand in the 5-minute interval before the FFR is triggered with electricity demand in the intervals after the deployment.

Evaluation Objectives

The main objectives of this evaluation were to measure the demand response grid services impacts, to assess the accuracy of the third-party aggregator OATI forecasts, and to verify that OATI delivered the

[6] For more details about the methods OATI uses to generate the forecasts, see Cadmus memo (November 20, 2020) included as Exhibit B in HECO's November 25, 2020, filing with Hawaii Public Utilities Commission (Docket No. 2007-0341). https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A20K27A81537F01781

[7] For more information about the performance factor calculations, see Exhibit A and Exhibit C of the GSPA. https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A19H12A85058F00420

grid services that it reported to HECO. More specifically, this evaluation answered the following questions:

- **Impact Assessment**: What were the achieved kilowatt impacts by capacity build, capacity reduction, and FFR demand response grid service?
- **Settlement Verification:** Does the delivered capability using the baseline methods in the GSPA #1 and calculated from telemetry data align with what OATI reports?
- **Settlement Accuracy:** Can the GSPA baseline methods used to estimate delivered capability accurately and precisely measure the counterfactual?
- **Forecast Accuracy**: How does OATI's forecast of grid services compare to the evaluated results? Are there key trends in how the forecast accuracy changes over time?

Evaluation Methodology

Working with the Cadmus team, HECO designed and implemented a randomized controlled trial (RCT) field experiment to evaluate the demand response grid services from GIWHs in the GSPA #1. At the beginning of the experiment, Hawaiian Electric and the Cadmus team randomly assigned half of water heaters to a treatment group and the other half to a control group. Water heaters in the control group did not experience any demand response events and provided a baseline for estimating the impacts of the demand response. Since water heater were randomly assigned to the treatment group or control group, experiencing a demand response event should have been uncorrelated with the energy consumption and other characteristics of water heaters, and comparison of the demand of the treatment and control groups should provide an unbiased estimate of savings.

The field experiment ran from January 21, 2021, to June 1, 2021, and included 1,464 GIWHs on O‘ahu: 733 in the treatment group and 731 in the control group.[8] During this period, Hawaiian Electric initiated 27 capacity build and 37 capacity reduction demand response events. Also, one FFR demand response event was automatically triggered by the GIWHs in response to a drop in frequency detected on HECO’s system.

Table 2 shows the number, durations, and beginning and ending times for the demand response events. The ***Error! Reference source not found.*** provides the event dates and starting and ending times for all events during the RCT.

Table 2. RCT Demand Response Events

Event Type	Number of Events	Average Length (hr:min:sec)	Event Window
Capacity Build	27	04:00:00	10:00 a.m. - 2:00 p.m.
Capacity Reduction	37	01:17:50	5:00 p.m. - 9:00 p.m.
FFR	1	00:04:53	4:48 a.m. - 4:53 a.m.

Evaluation Data

Shifted Energy provided the evaluation consultants with 5-minute interval average electricity demand (kilowatt) data for 1,367 GIWHs in the experiment and 15-minute interval demand data for the remainder. The Cadmus team analyzed telemetry data because many of the participating water heaters were located in master-metered buildings and many water heaters in buildings with individually metered apartments did not have AMI interval data.

The telemetry interval consumption data were generally complete and clean, with relatively few water heaters having missing or erroneous consumption readings. A small number of water heaters did not

[8] During the RCT, OATI continued to enroll new customers in water heater demand response. These customers participated in demand response events but were not included in the RCT and their impacts are not evaluated in this report.

return reads for more than 30% of 15-minute intervals, which was likely attributable to poor cellular reception at these locations. As Table 3 shows, after removing these water heaters and four other water heaters in the extreme tails of the distribution (two water heaters with average demand equal to zero and two with average demand more than 2.5 times the next highest average demand), there were 1,336 water heaters remaining the analysis sample.

Table 3. Evaluation Analysis Sample Selection

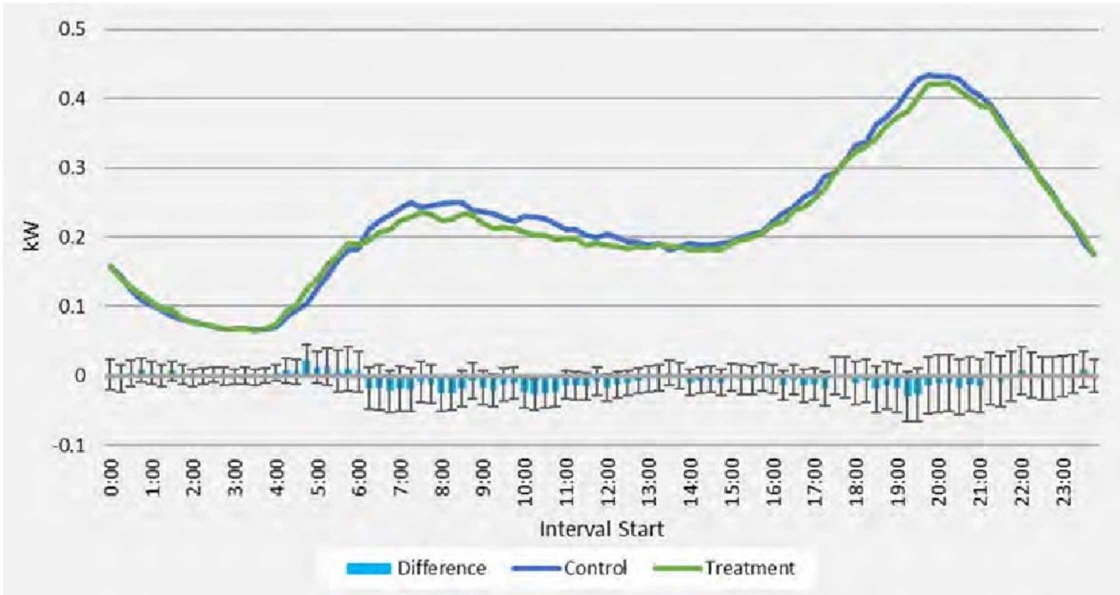
Group	Devices Included in RCT (n)	Devices Included in Telemetry Data (n)	Devices Dropped from Analysis (n)	Devices Included In Final Analysis (n)
Control	730	689	17	672
Treatment	733	678	14	664
Total	**1,463**	**1,367**	**31**	**1,336**

The Cadmus team also performed several telemetry data cleaning and preparation steps, including removing duplicate readings and synchronizing the timestamps of a small number of readings to end on 5-minute intervals during the hour. For the analysis of the capacity build and capacity reduction events, the team aggregated the 5-minute interval kW data to 15-minute intervals. Any 15-minute interval containing one or more missing 5-minute intervals was dropped from the analysis sample. The team estimated the FFR impacts using the 5-minute interval kW. After data cleaning, the analysis sample included 672 water heaters in the control group 664 in the treatment group.

Validation of the RCT

The Cadmus team validated the RCT design by comparing the 15-minute interval electricity demand of water-heaters in the treatment and control groups on non-event, non-holiday weekdays during the RCT period. Figure 1 shows electricity demand for the groups tracked each other closely and there are not statistically significant differences between the groups for most intervals, suggesting that the randomization appears to have resulted in well-balanced groups.

Figure 1. Electricity Demand of Treatment and Control Group Water Heaters on Non-event Days



Notes: The figure shows water heating electricity demand on non-event, non-holiday weekdays during the experiment and the difference. The difference in average consumption per water heater between the treatment and control group was estimated in a regression of individual water heater consumption on 15-minute interval of the day fixed effects and interval fixed effects interacted with an indicator for assignment to treatment. The error bars show 95% confidence intervals, and the standard errors were clustered on water heaters.

Figure 1 also shows that across all weekday hours, RCT water heaters exhibited relatively low average electricity demand, with demand peaking in the morning at about 0.25 kW and again in the evening at about 0.45 kW. As the typical water heater in the RCT demanded between 3.5 and 4.5 kW while heating, the demand data show that only a small percentage of water heaters were heating at each point in time.

Validation of Vendor Telemetry Data

As noted above, the Cadmus team analyzed kilowatt telemetry data provided by OATI because of the unavailability of AMI meter data. To validate the accuracy of the telemetry interval demand data, the team installed[9] data loggers on nine GSPA participant water heaters and compared the telemetry and logger demand.[10]

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9 Due to travel restrictions to Hawai'i resulting from the COVID-19 pandemic, the Cadmus team was not able to travel to O'ahu to perform the data logger installation as planned. Instead, Shifted Energy performed the logger installations under the direction of the Cadmus team. In addition to configuring the data loggers before sending them to Shifted Energy, the Cadmus team also conducted remote verification of every logger installation to confirm that Shifted Energy had correctly installed the equipment and that the loggers were recording valid data.

10 Two loggers were installed in housing units that appear to have been unoccupied and were excluded from the comparison.

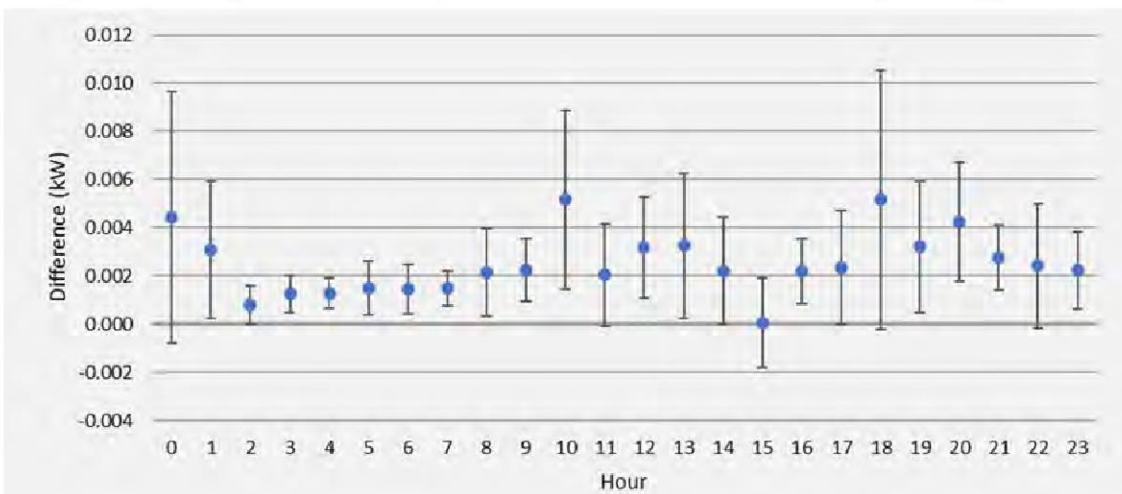
Table 4 presents summary statistics from the validation analysis. Across the portion of the RCT period during which the loggers were correctly calibrated and recording data (May 12 to May 31, 2021), the correlation coefficient between the logger data and telemetry data across all water heaters was 0.999 with a mean absolute percent error of 3.1%.

Table 4. Telemetry Data Validation Summary Statistics

Correlation Coeff.	Mean Diff. (kW)	Mean Absolute % Error
0.999	0.0025	3.09%

Figure 2 shows estimates of the average difference in kW values between the water heater telemetry data and the evaluation logger data by hour of the day. The differences were obtained from an OLS regression of the difference in kW on a set of hour-of-the-day fixed effects using data for all five minute intervals between May 12 and May 31, 2021.

Figure 2. Average kW Difference per Water Heater between Telemetry and Logger Data



Note: Estimates obtained from a regression analysis of difference in water heater electricity demand on hour-of-the-day fixed effects. See text for estimation details. Error bars show 95% confidence intervals. Standard errors were clustered on water heaters.

This comparison shows that the water heater telemetry data recorded nearly identical readings to those of the Cadmus team's data loggers. This suggests the telemetry data can be used for the purposes of evaluation.

Data and Methods for Other Evaluation Tasks

In addition to cleaning and validating telemetry data for the load impact analysis, the Cadmus team also used OATI-provided forecast and other settlement report data to conduct the assessment of settlement calculation methods, assessment of settlement accuracy, and the analysis of forecast accuracy.

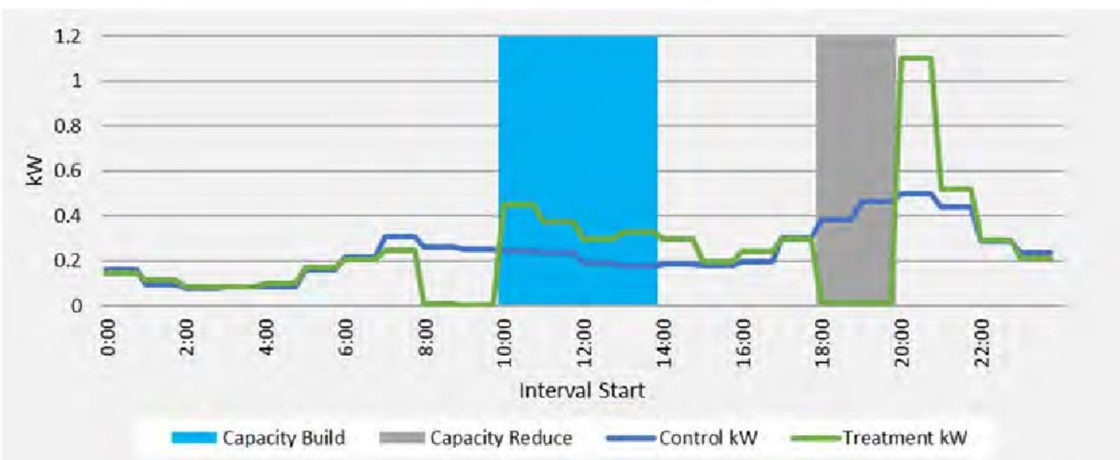
Evaluation Results

This section provides results from the evaluation of the GSPA #1.

Load Impacts Analysis

The Cadmus team estimated the GSPA demand impacts by comparing the demand of water heaters in the randomized treatment and control groups. Figure 3 illustrates the comparison between the treatment and control groups' average demand per water heater during a capacity build (10:00 a.m. to 2:00 p.m.) and a capacity reduction (6:00 p.m. to 8:00 p.m.) demand response event on March 2, 2021. At 8:00 a.m., the treatment group was shut off for the two hours preceding the start of the capacity build event at 10:00 a.m. to shift water heater load into the midday period. All capacity build events during the RCT were preceded by a controlled reduction in load. During the capacity build event, the treatment group's average demand was higher than the control group's average demand, reflecting the impacts of the treatment. During the capacity reduction event, devices in the treatment group were shut off from 6:00 p.m. to 8 p.m. After the event ended, the demand of treatment group water heaters spiked sharply (to over 1 kW in this example) as the devices were allowed to switch back on and resume heating water after being shut off during the first half of the typical evening hot water consumption period.[11]

Figure 3. Average Demand Curves During Capacity Build and Capacity Reduction Events, March 2, 2021



Notes: Figure shows unconditional mean electricity demand for water heaters in the RCT treatment and control groups on March 2, 2021. Hourly electricity demand calculated using 5-minute interval water heater electricity demand telemetry data.

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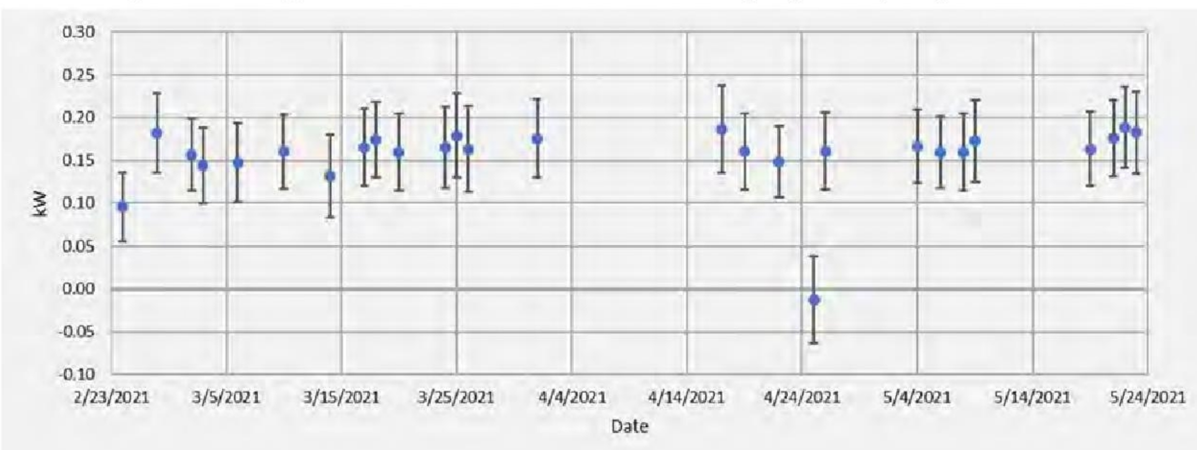
11 Unlike capacity reduce events, capacity build events do not produce any reduction in load after the events end. This is because capacity build events do not raise the storage temperature of the water heaters and, thus, do not store any additional energy. Instead, capacity build is achieved by deferring consumption from the 8:00 to 10:00 a.m. period to the 10 a.m. to 2 p.m. period.

While the grid services impacts can be estimated as a simple difference of mean demand between the treatment and control groups, the Cadmus team used panel regression models of water heater electricity demand to estimate the demand impacts from capacity build, capacity reduction, and FFR events.[12] A separate regression of 15-minute interval electricity demand was estimated for each event only using data for the event day. Independent variables included in the model were time-of-day (15-minute interval) fixed effects, each device's average non-event day usage (calculated at the monthly level) interacted with time-of-day fixed effects, and assignment to the treatment group status interacted with the time-of-day effects. The coefficients from the time-of-day and treatment interactions represent the impacts from the grid services. The demand response grid services impact estimates presented in this report are robust, that is, they do not change significantly when alternative estimation methods and model specifications are used.

Capacity Build

Figure 4 and Figure 5 show the average treatment effect estimates (in kilowatts per water heater and as a percentage of the reference load, respectively) for each of the 27 capacity build events during the RCT study period. Appendix A includes tables with the impact estimates, standard errors, and reference loads for each event.

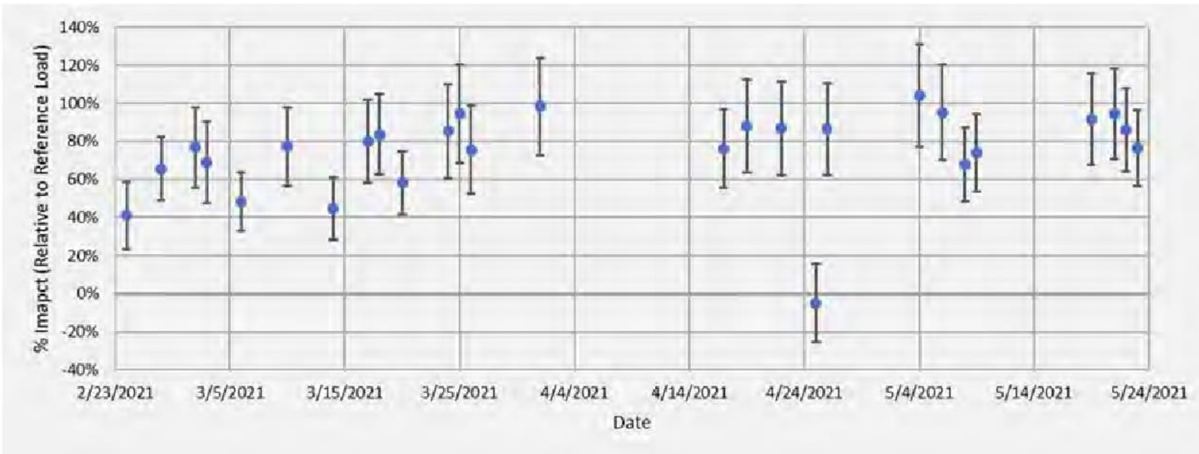
Figure 4. Average Treatment Effect Per Water Heater (kW) for Capacity Build Events



Note: Estimates obtained from ordinary least squares (OLS) regressions of water heater demand. See text for details. Error bars represent the 95% confidence interval for impact estimates. Standard errors were clustered on water heaters.

[12] The regressions provide more precise impact estimates and the standard errors of the estimated coefficients account for correlations in a water heater's electricity demand over time.

Figure 5. Percentage Treatment Effects for Capacity Build Events



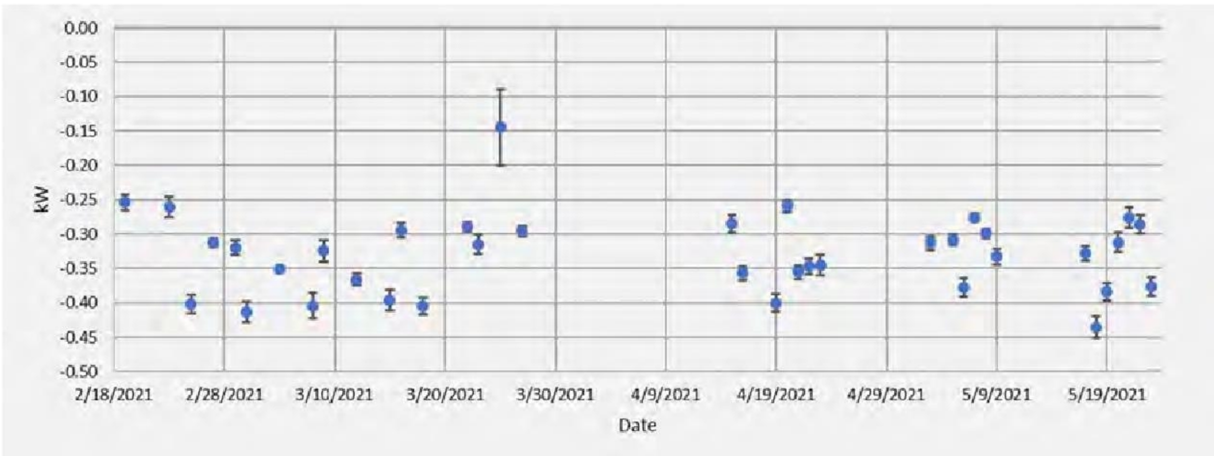
Note: Percentage impacts estimated as kilowatt impact divided by the average reference load for treatment group water heaters. Error bars represent the 95% confidence interval for impact estimates. Standard errors were clustered on water heaters.

The capacity build events resulted in impacts per water heater ranging from 0.15 to 0.20 kW and averaging 0.159 kW across hours of all capacity build events. These impacts represent an average increase of 76% of baseline water heating demand during the 10:00 a.m. to 2:00 p.m. period. Some events doubled baseline demand, as shown by the percentage impacts exceeding 100%. Capacity build demand response provided consistent increases in demand across events, with the exception of the April 25, 2021, event (which appears to have failed, producing no statistically significant increase in demand.)

Capacity Reduction

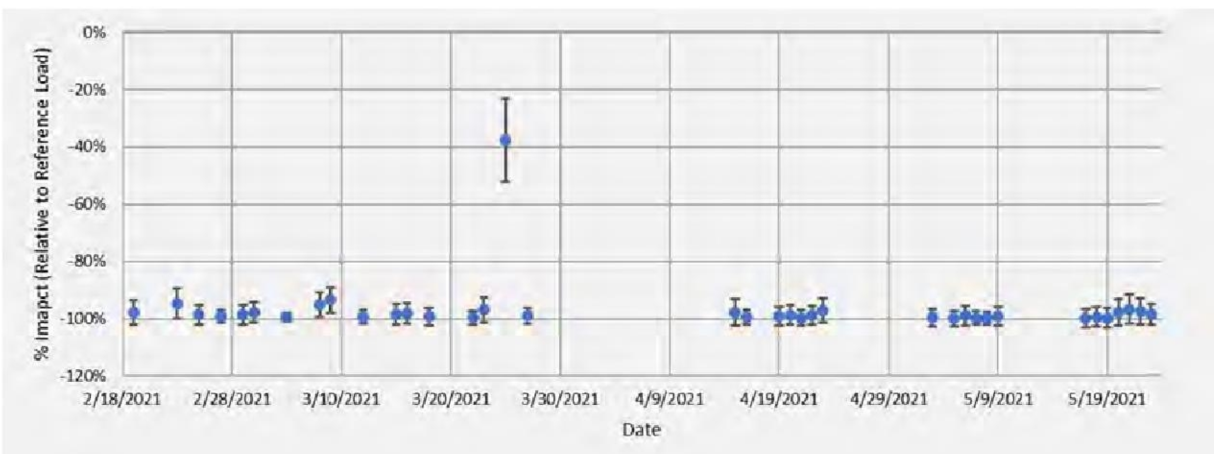
Figure 6 and Figure 7 show the average treatment effect estimates (in kilowatt per water heater and as a percentage of the reference load, respectively) for each of the 37 capacity reduction events during the RCT study period.

Figure 6. Average Treatment Effect Per Water Heater (kW) for Capacity Reduction Events



Note: Estimates obtained from OLS regressions of water heater demand. See text for details. Error bars represent the 95% confidence interval for impact estimates. Standard errors were clustered on water heaters.

Figure 7. Percentage Treatment Effects for Capacity Reduction Events



Note: Percentage impacts estimated as kW impact divided by the average reference load for treatment group water heaters. Error bars represent the 95% confidence interval for impact estimates. Standard errors were clustered on water heaters.

Capacity reduction events were highly successful at reducing electricity demand to near zero and performed consistently, resulting in an average reduction of 0.321 kW per water heater or a 95% reduction relative to baseline across all events.[13]

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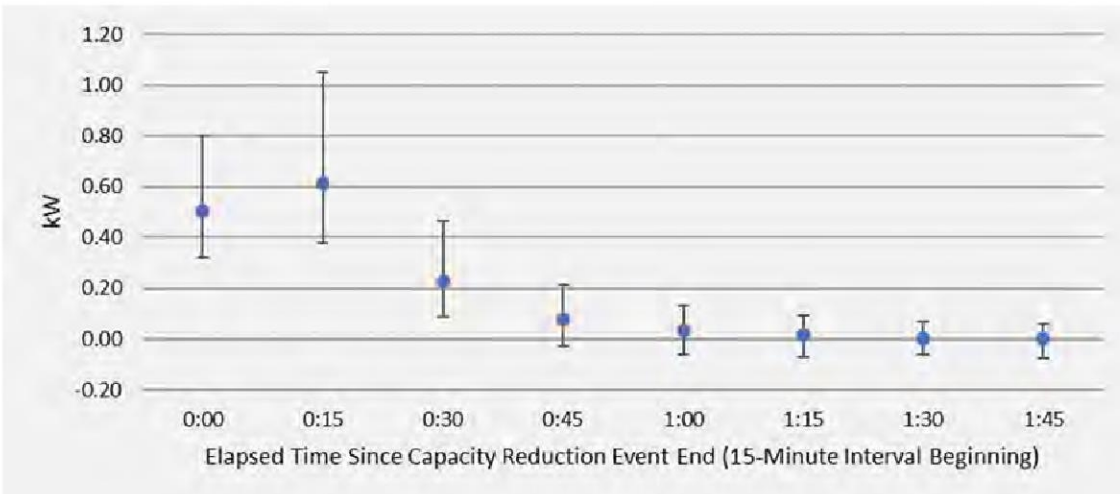
[13] The estimated standard errors are smaller and the confidence intervals are generally much narrower for capacity reduction events than for capacity build events due to lower variance of electricity demand during capacity build events, during which time water heaters were typically shut off for the entirety of the event. In contrast, with capacity build events, water heaters cycled on and off to build capacity.

Post-Capacity Reduction Event Snapback

Though capacity reduction events resulted in large and consistent reductions in demand during the events, they also produced very large increases in water heating demand in the intervals immediately following events. This snapback is expected as these events shut off water heaters during their typical evening consumption peaks and the water heaters must run more than usual following the events to reheat the tank. Figure 8 depicts the estimated snapback from the capacity reduction events.

Figure 8. Demand Snapback Following Capacity Reduction Events



Note: Markers show the average increase in electricity demand per water heater after capacity reduction events. The error bars show the 5th and 95th percentiles of the distribution of estimates of snapback across the 37 events.

Across all events, capacity reduction events increased demand by an average of 0.5 to 0.6 kW per treated water heater in the half hour following the event. This increase was more than 160% of baseline demand. This snapback typically lasted for at least 45 minutes after the events. In the interval 15 to 30 minutes after the event ended, the 95th percentile of snapback across events exceeded 1 kW per water heater. This snapback in demand is expected as these events shut off water heaters during their typical evening consumption peaks and the water heaters must run more than usual following the events to reheat the tank.

FFR

During the one FFR event in the study period, both treatment and control group water heaters were shut off by the implementer's devices when the devices detected the underfrequency condition. This

FFR event occurred on March 29, 2021, at 4:48:24 a.m., and the frequency returned to normal at 4:53:02 a.m.[14]

As FFR was not implemented as an RCT, the Cadmus team could not compare the treatment and control groups and therefore modified its analysis approach to estimate impacts for both the treatment and control group relative to their predicted baseline demand in each five-minute interval.[15] Figure 9 shows the average metered (actual) demand and the average reference (model predicted baseline) demand per device around the FFR event. The figure shows that in the intervals including the underfrequency detection at 4:48:24 and the following interval, average water heater demand drops nearly to zero. In following intervals, demand then rises as the devices allow the water heaters to turn back on.

Figure 9. Electricity Demand during FFR Event on March 29, 2021

Note: Reference load obtained from regression analysis of water heater electricity demand. See text for details. The FFR event began at 4:48 a.m. and frequency returned to the normal range at 4:53 a.m.

As the FFR event partially overlapped two 5-minute intervals (4:45 to 4:50 and 4:50 to 4:55), the FFR impacts were estimated in two steps. First, the Cadmus team estimated the demand reduction for all intervals between 3:45 a.m. and 8:00 a.m. using regression analysis of the interval electricity demand data, shown in Figure 10. Second, the team calculated a scaling factor representing the proportion of

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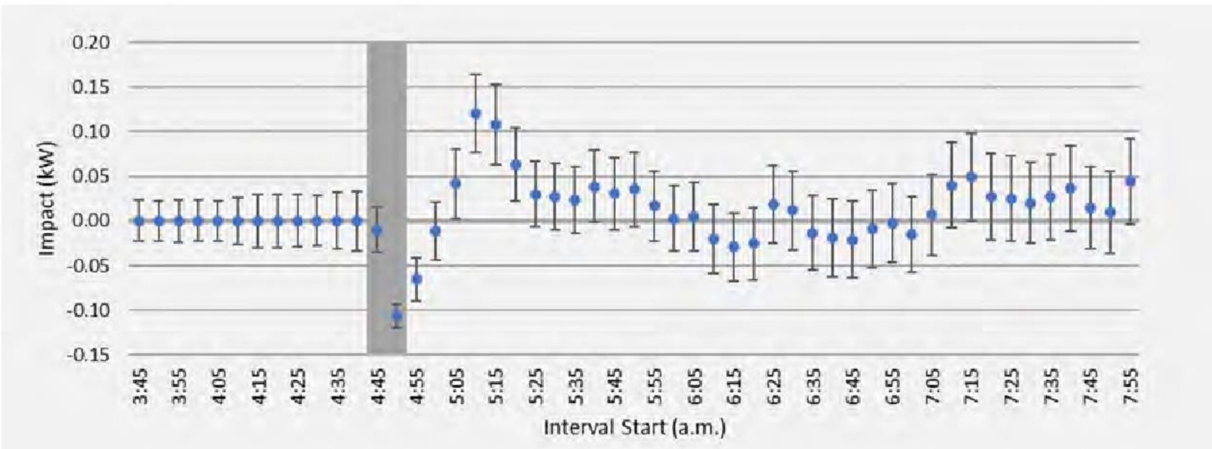
14 Starting at 4:48:24 a.m, enrolled water heater devices began detecting grid frequencies below the 59.7 Hz trigger and began to shut off. Due to local frequency measurement at each device, these detection times varied slightly, but were reported to be no longer than nine seconds. Around four and a half minutes later, beginning at 4:53:02, the devices began to detect that the frequency was corrected. Following detection, the devices allowed the water heaters to turn back on in small groups at staggered intervals (from a few seconds to 15-20 minutes after frequency correction detection.)

15 Baseline demand was estimated in an OLS regression of water heater 5-minute interval demand on a set of 5-minute interval of the day fixed effects and the fixed effects interacted with an indicator for assignment to treatment. The model was estimated with data for the FFR event day and all non-holiday, non-event days in March 2021 and April 2021. The coefficients on the interval fixed effects are estimates of baseline demand. The coefficients on the interaction variables provide estimates of the FFR kilowatt impacts per water heater.

the first interval affected by the FFR event and divided the estimated impact for this interval by the proportion to produce the average impact estimates. During the first event interval, the average proportion of seconds in which FFR was active in the interval was 93.3 seconds or 31.1%. Multiplying the impact estimate for the first interval (=0.01) by 1/0.311 yields an estimate of the FFR impact during the first interval equal to 0.032 kW.

Figure 10. Average Impact Per Water Heater (kW) for FFR Event on March 29, 2021



Note: kW Estimates are for 5 minute intervals. Impact estimates obtained from a regression analysis of water heater electricity demand. See text for estimation details. Error bars show 95% confidence intervals. Standard errors were clustered on water heaters.

During the first interval (4:45 to 4:50), FFR resulted in roughly a 30-watt demand reduction (10 watts before scaling), which was statistically significant but less than the expected impact of around 0.1 kW. During the second interval, the FFT impact exceeded 0.1 kW. The estimates show that the FFR grid service did provide demand reductions as expected, though the team cannot verify whether devices responded as quickly as specified in the GSPA.[16] In addition, the impacts reported here reflect FFR's performance during just one event, so conclusions concerning FFR's performance are less robust than for capacity build or capacity reduction events, which are based on a much larger sample of events across the study period. Future studies utilizing higher-frequency data could provide additional information about FFR's performance as a grid service under GSPA #1.

Potential Impacts of Demand Response on Grid Stability

Based on the evaluation results, the Cadmus team determined that OATI delivered the grid services within the requirements of the contract. While the grid services contracted under GSPA1 are relatively small, two aspects of their performance could become issues if the aggregated resource under GSPA1 were expanded:

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[16] The frequency of the telemetry data available (5-minute intervals) relative to the duration of the FFR event (less than five minutes), as well as the low average water heating demand during the early morning when this event occurred make precise estimation of FFR's impacts during the first interval challenging.

- Water heater electricity demand after capacity reduction events was high compared to baseline demand. The GSPA1 capacity ramp rate requirements limit the total amount of post-event snapback; however, HECO could impose more stringent ramping requirements in future GSPAs if the amount of snapback were to risk grid stability.
- Capacity build events did not show a consistent, sustained increase in load but showed a relatively volatile (i.e., spiky) grid service delivery during the event. For GSPA1, capacity build performance is assessed using a one-hour interval demand, which obscures within-hour volatility. For subsequent GSPAs, performance assessment will be measured for 15-minute intervals to encourage a more consistent response during capacity build events.

HECO will continue to monitor ramp rates and event performance and implement or modify the Grid Service requirements as needed to ensure their desired operation.

Evaluation of Settlement Calculation Methods

A primary goal of this evaluation was to verify that settlement methods described in the GSPA were accurately calculated by the vendor. While the Cadmus team reviewed all the invoice components, its primary focus was to verify that the reported delivered capability of each resource was accurate. Delivered capability is the estimate of grid service load impacts as calculated by settlement baselines prescribed in the GSPA. Settlement was done on the basis of an event performance factor, which quantified the degree to which the delivered capability, itself calculated by a baseline method, aligned with the forecast for that capability in each event period. Table 5 summarizes the methods described in the GSPA that the Cadmus team sought to replicate. The baseline method for FFR events uses the interval directly prior to the event to establish the baseline, while capacity build and capacity reduction events rely on an unadjusted ten-of-ten baseline of similar non-event days. The event performance factors relate the delivered capability—the average event interval for FFR and each hour of the event for the Capacity grid services—to the forecasted value in that hour. Note that as the performance factors are equal to one only when the delivered capability is equal to the forecast and less than one both in cases where the delivered capability is higher or lower than the forecast.

Table 5. Settlement Delivered Capability and Performance Factors

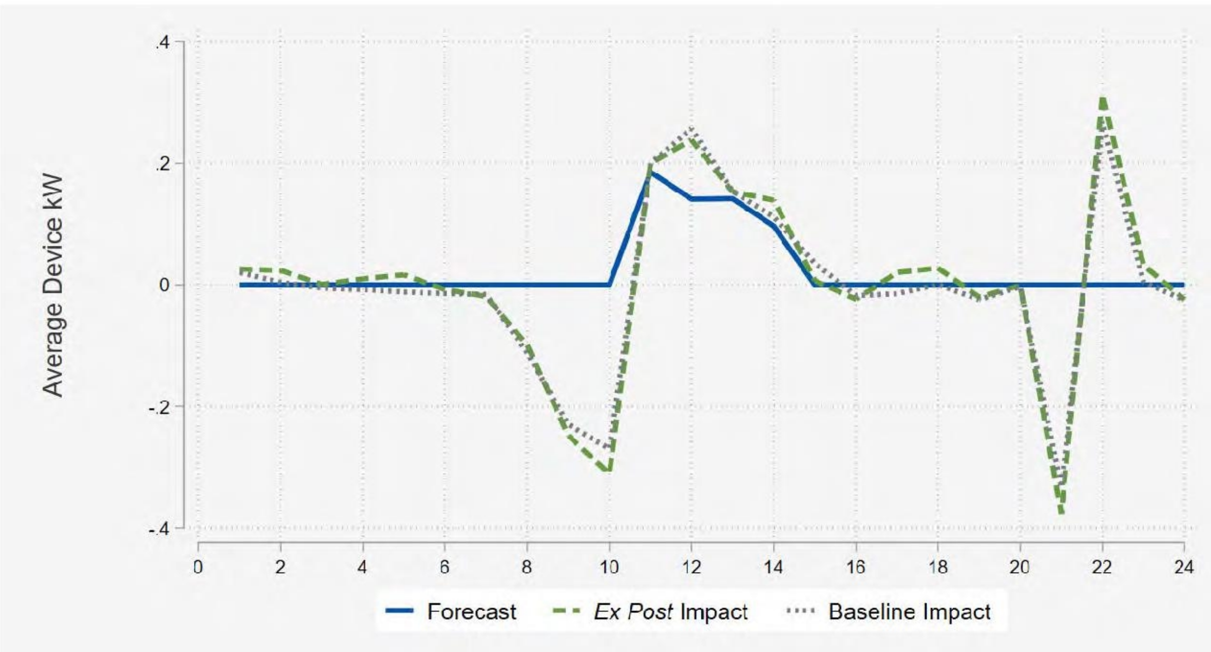
Grid Service	Delivered Capability	Event Performance Factor
FFR	$D_e = kW_{t-1} - \left(\frac{\sum_{i=1}^{n} kW_i}{n}\right)$	$PF_e = \left(1 - \left\|1 - \left(\frac{D_e}{F_e}\right)\right\|\right)^2$
Capacity Build/ Reduction	$D_{e,i} = \left(\frac{\sum_{d=1}^{10} kW_{e-d,i}}{10}\right) - kW_{e,i}$	$PF_e = \frac{\sum_{i=1}^{n}\left(1 - \left\|1 - {D_{e,i}}/{F_{e,i}}\right\|\right)}{n}$

Variable	Definition
$\boldsymbol{D_e}$	Delivered capability in event e
$\boldsymbol{D_{e,i}}$	Delivered capability in hour i of event e

F_e	Forecasted capability average over event e
$F_{e,i}$	Forecasted capability in hour i of event e
PF_e	Performance factor of event e
kW_i	Observed demand in hour i
n	Number of hours in event

In general, the Cadmus team noted a relatively close correspondence between the evaluated load impact results described above (*ex post* impacts) and the delivered capability calculations prescribed by the GSPA. An example of the impact estimate alignment, compared to the forecast for a single capacity build event day is shown in Figure 11. As discussed in the *Settlement Accuracy* section of this report, this alignment is likely due to the stability of water heating loads from day to day, meaning that a ten-of-ten baseline can produce accurate impacts.

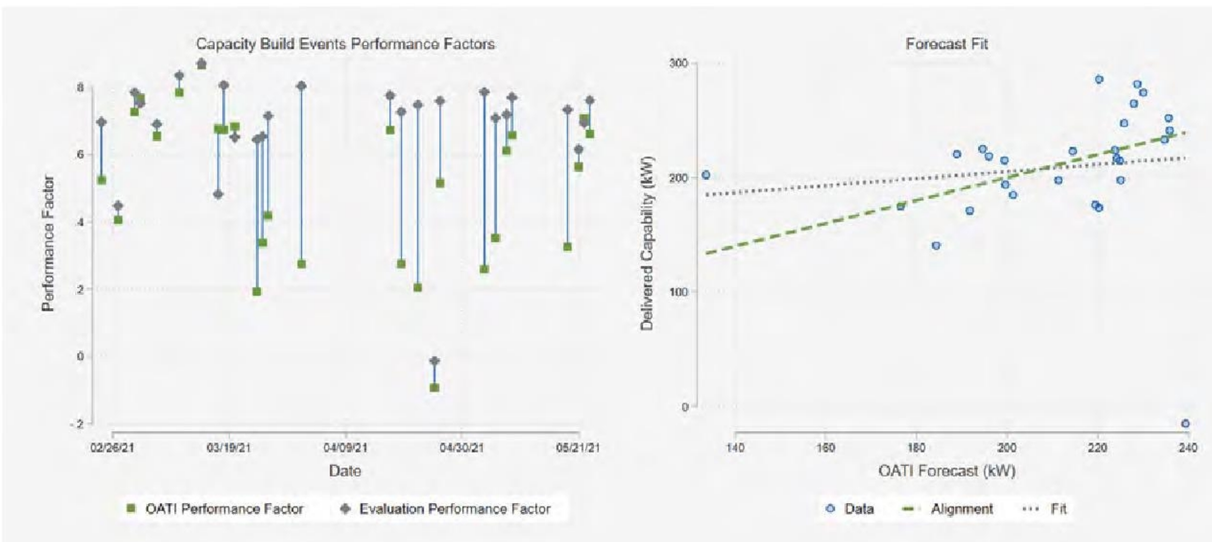
Figure 11: Impacts Calculated by Baseline Compared to Load Impacts and Forecast



The Cadmus team computed the delivered capability and performance factors over the event period only and compared them to the reported event performance factors provided by OATI. Figure 12, Figure 13, and Figure 14 show the results of this analysis for the capacity build events, the capacity reduction events, and the single FFR event, respectively. In each graph, the left pane compares the performance factors provided by OATI with the performance factors calculated by the Cadmus team, by date, to show the trend in alignment over time. The right pane compares the aggregate forecasted capability compared to the delivered capability calculated by the team. In those panes, the 45-degree line (in green) represents the alignment of the results if the evaluation results exactly matched the forecast, while the grey fit line shows the linear best fit line between the data points in blue. In essence, the left figure shows the accuracy of OATI's settlement calculations, while the right figure shows the accuracy of its forecasts.

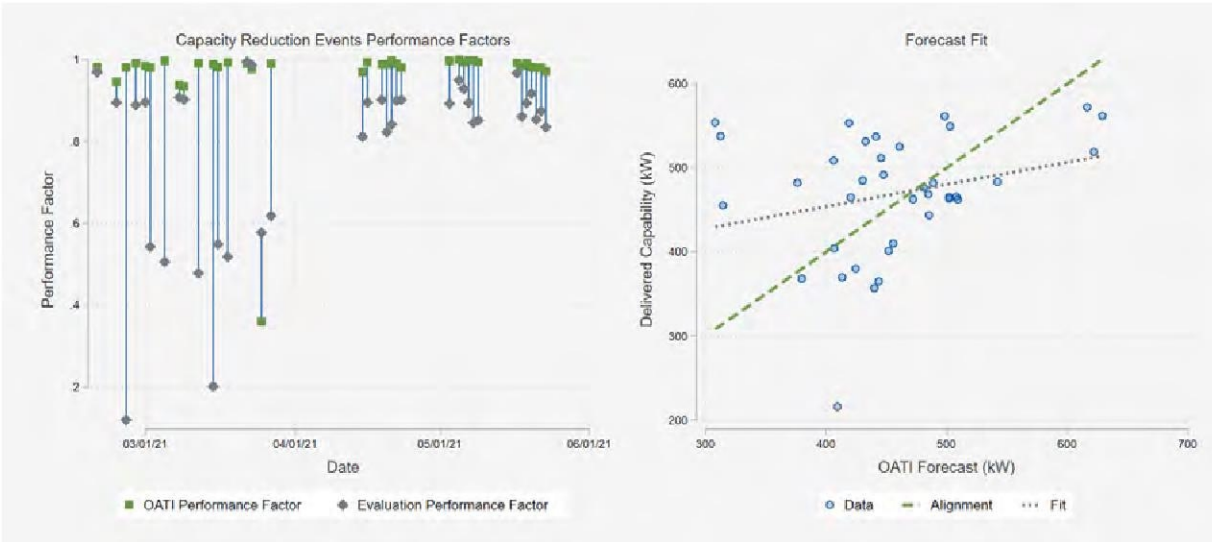
For capacity build events, the Cadmus team generally calculated higher performance factors than what was reported in the OATI settlement reports. This difference was greatest on weekday events compared to weekend events. The GSPA requires similar days to be used for the weekday and weekend event baselines—weekend days should be used only for weekend events and weekday days for weekday events. The Cadmus team tried replicating baselines using only weekdays, only weekends, and all days to try to replicate OATI impacts, but could not match the reported results exactly. The performance factors reported here are using like days (weekdays for weekday events and weekends for weekend events.)

Figure 12. Capacity Build Events Performance Factors and Forecast Trends



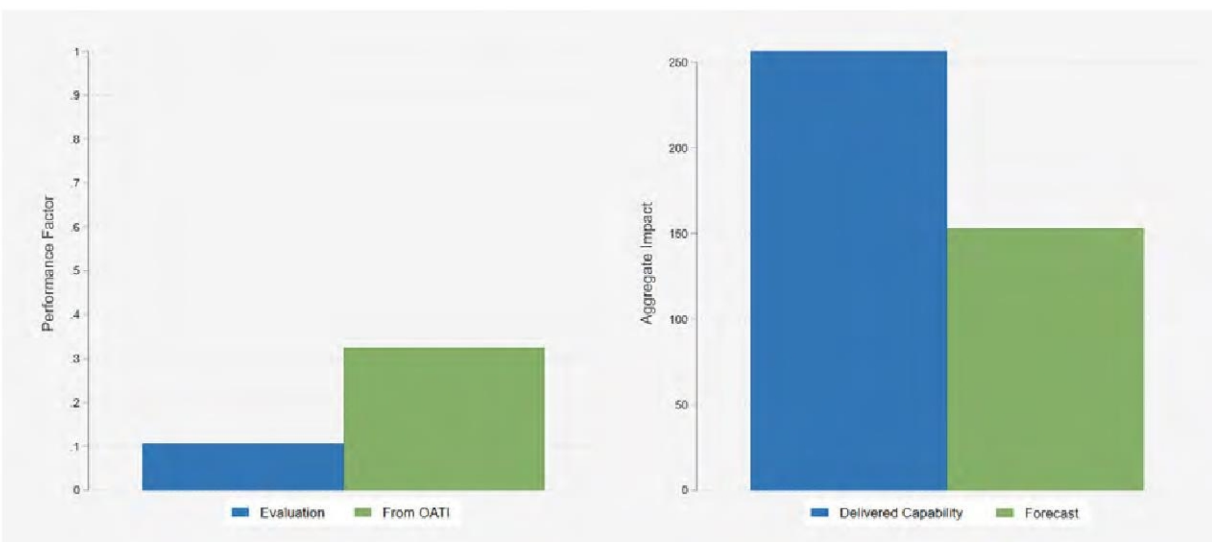
For capacity reduction events, the Cadmus team generally calculated lower performance factors than OATI reported, though the performance of the water heaters during capacity reduction events was generally higher than capacity build events. Also, February and March events had worse performance than events later in the evaluation period. The explanation for the difference in results from month to month is not clear. Unlike capacity reduction events, there is not a clear distinction between weekday and weekend events—instead there is a temporal shift in results. As discussed in the *Forecast Accuracy* section of this report, the Cadmus team notices a clear trend in forecast improvement over time for the capacity build and reduction events. It is possible that the forecast improvement in later months is a major driver of improved performance factors.

Figure 13. Capacity Reduction Events Performance Factors and Forecast Trends



For the single FFR event, the Cadmus team calculated a higher delivered capability than what was forecasted. Because of the penalty for over-delivery embedded in the performance factor calculation, the performance factor of this event is low.

Figure 14. Fast Frequency Response Events Performance Factors and Forecast



Overall, while the evaluated and OATI-reported event performance factors did not match what was reported by OATI, the reported performance was not systematically higher than what was found in this analysis. In general, the evaluated performance factors were higher than those reported by OATI for capacity build events and lower for capacity reduce events. In both the evaluator's analysis and in the reported OATI results, performance factors for capacity reduction events were generally higher than those for capacity build. The source of the discrepancy between the calculated results and those reported by OATI was not determined, but in practice could be due to slightly different different versions of the forecast data, event timestamps, or inconsistent application of the baseline methods. For future GSPA settlement rules, we recommend vendors provide additional data to support the verification of event performance factors. This supplemental data may include information about the baseline days used to construct the reference load for each event and aggregate participant 5-minute loads on each baseline day. Along with the forecasts currently provided as part of the GSPA, these data would allow HECO to replicate settlement performance factors with more certainty.

Assessment of Settlement Accuracy

For the second part of the evaluation, the Cadmus team determined whether the baseline methods described in the GSPA were capable of accurately quantifying the load increases or reductions associated with these grid service events. The team undertook a baseline accuracy assessment to quantify the error associated with the methods of estimating the counterfactual and, therefore, the delivered capability.

The method to conduct this assessment is relatively simple. The Cadmus team picked pseudo-event days: non-event days similar to events but where no event was actually called. For each of these pseudo-event days, the team ran the baseline algorithm used for settlement calculations as if the pseudo-event days were actual event days. Because no event took place, the baseline result could be compared to the true observed loads. Any differences between the two during event periods represent error attributable to the baseline method. These differences were summarized using statistics representing two key variables of accuracy. The mean percent error (% error in the tables below) summarizes the degree to which the baseline tends to overstate or understate the true value on average. The normalized root mean squared error summarizes the variability in error from event to event (or hour to hour within an event). Together, these variables represent the accuracy (% error) and precision (root mean squared error) of a baseline. The best baselines are both accurate and precise.

Table 6 summarizes these key statistics across all pseudo-event days assessed in this analysis, which included six pseudo capacity build events, eight pseudo capacity reduction events, and five pseudo fast frequency response events. The table shows that observed usage for the average device during the pseudo-event period, the average baseline usage for the same period, and the normalized RMSE (a measure of precision) and percent bias (a measure of accuracy). The magnitude of bias is less than ±5% in all three grid services. The load impacts calculated by the Cadmus team were approximately 76% for capacity build events, 95% for capacity reduction events, and at least 28% for FFR.[17] In all cases, the magnitude of the bias associated with the baseline methods was substantially lower than the magnitude of the reductions delivered in the events themselves. As a result, the Cadmus team finds no need to recommend changes to the GSPA-prescribed baseline method of the baseline algorithms.

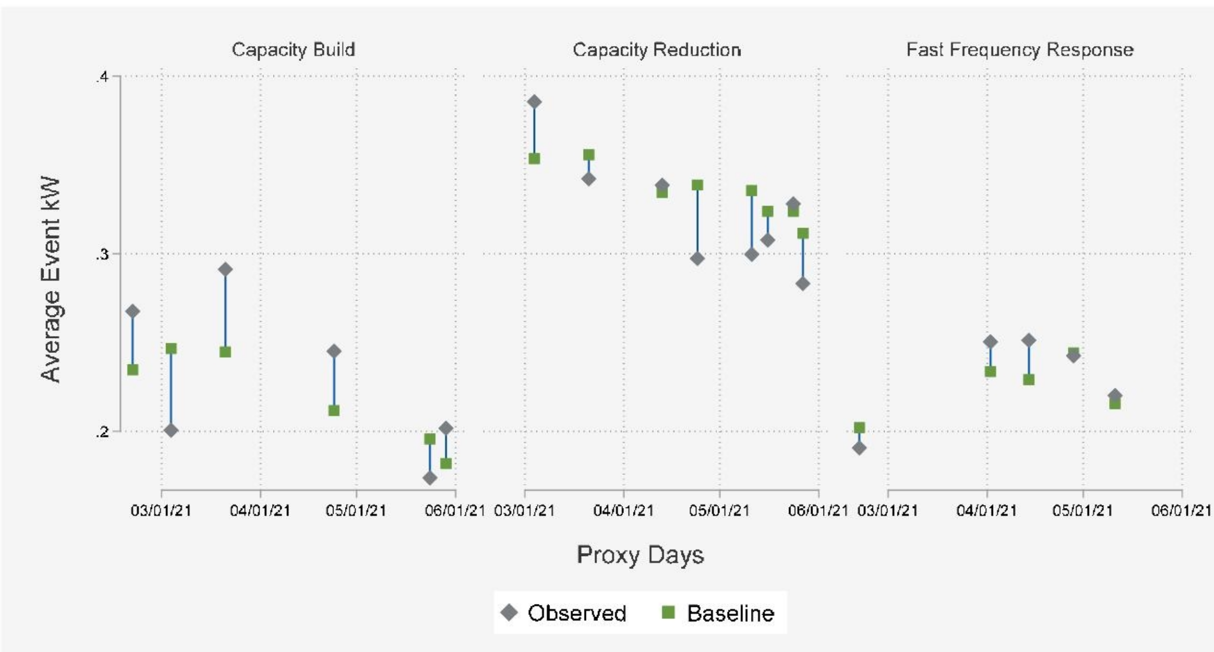
[17] This result is based on the first interval of the event.

Table 6. Accuracy and Precision Summary by Grid Service

Grid Service	Usage (kW)	Baseline (kW)	Normalized RMSE (%)	Bias (%)
Fast Frequency Response	0.23	0.22	5.88	-2.63
Capacity Build	0.23	0.22	15.22	-4.69
Capacity Reduction	0.32	0.33	7.98	3.68

Figure 15 compares the observed event-hours loads from the telemetry data and the predicted loads from the baseline calculations for each of the pseudo-events. The difference between the observed and baseline loads are the baseline errors for each pseudo-event. Loads during capacity build events tend to be lower—around 0.23 kW—and have larger errors than capacity reduction pseudo-events. This means that both on an absolute and percentage basis, capacity build events have higher errors than capacity reduction events, as was summarized in Figure 15. Errors for FFR were generally quite low, likely due to the short nature of events of this type. Baselines that have to accurately model two to four hours of consumption patterns, as in capacity build and reduce events, will naturally have more variation in load patterns than events that last one to two minutes only.

Figure 15. Baseline Errors for Each Pseudo-Event by Grid Service



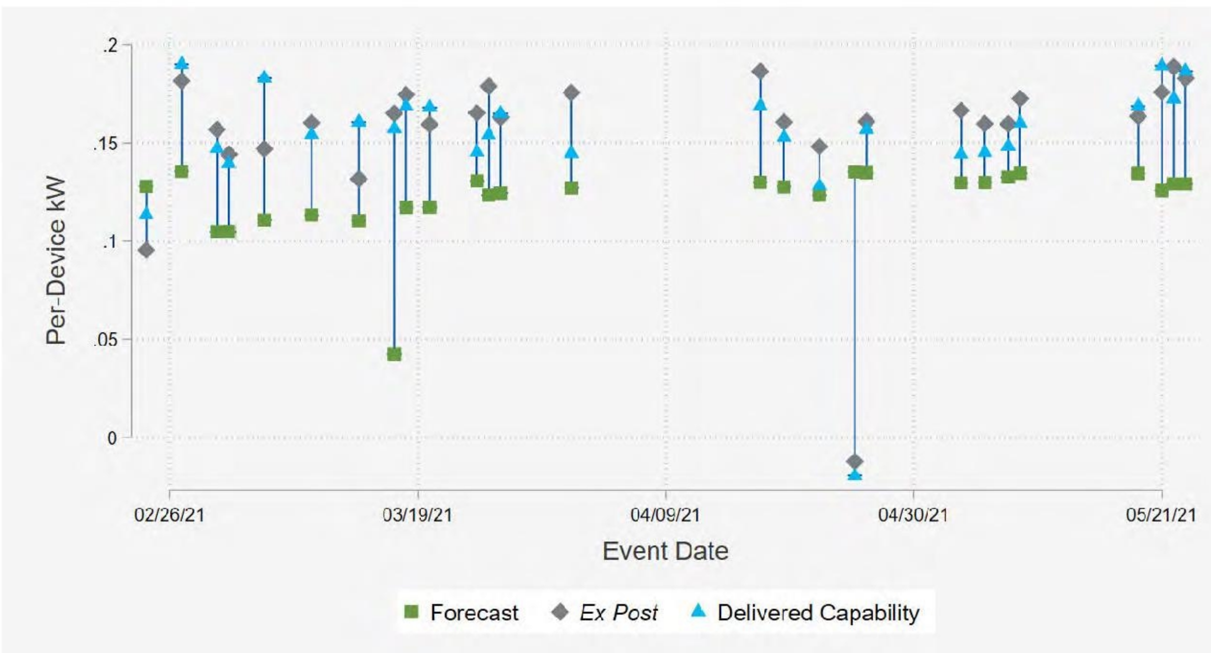
Assessment of Forecast Accuracy

As the final evaluation task, the Cadmus team assessed the accuracy of OATI forecasts for each of the three grid services. To determine the accuracy of these forecasts, the team compared the forecast values to the delivered capability and the *ex post* load impact estimates for each grid service event.

Findings

Figure 16 and Figure 17 compare the OATI forecast, the delivered capability, and the *ex post* impact for each of the capacity build and capacity reduction events, respectively. While all three values are reported for the sake of completeness, the forecast accuracy in all subsequent sections are against the *ex post* impacts as these values represent the ground truth of the load shed or load build in each event. The Cadmus team found that, on average, the *ex post* impacts of events were higher than both the OATI forecast and the delivered capability. The forecasts tended to improve over time, with estimates of forecasted capability more closely aligning with the estimated load reductions in April and May compared to February and March.

Figure 16. Comparison of Capacity Build Forecast and Impacts

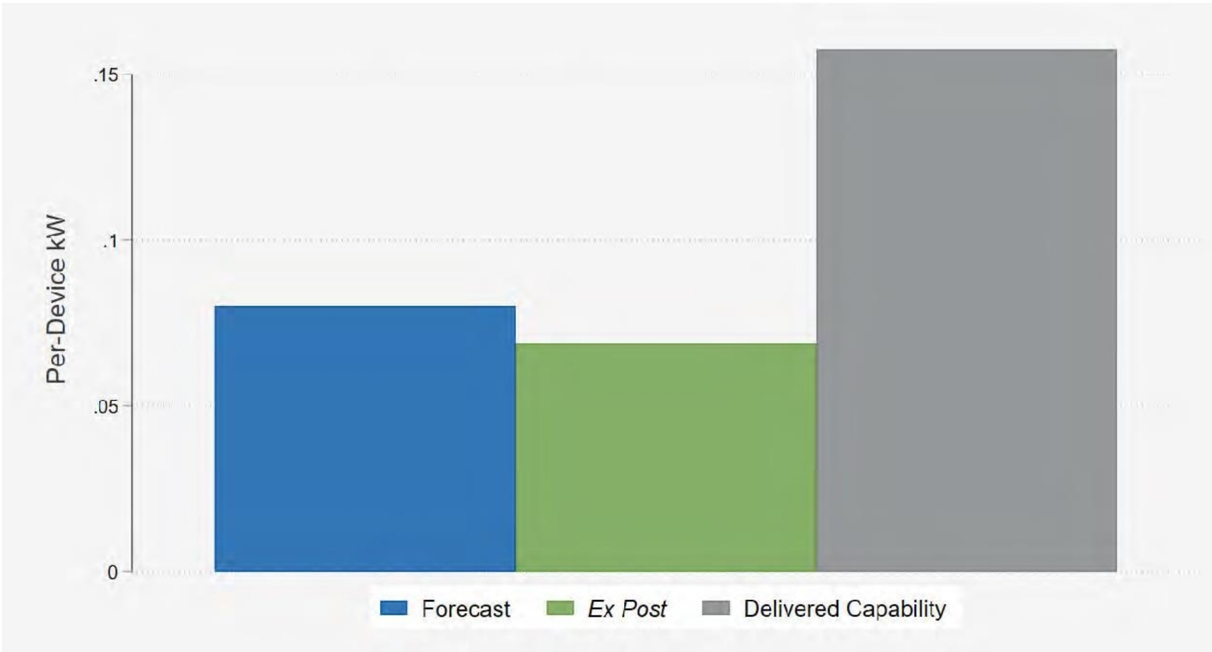


Capacity reduction events show a similar trend in improvement over time, with forecasts, delivered capability, and *ex post* load impacts all quite similar in magnitude during April and May of the evaluation period. *Ex post* load reductions estimated by the Cadmus team again were higher than those forecasted or the delivered capability calculated using the baseline method.

Figure 17. Comparison of Capacity Reduction Forecast and Impacts

Figure 18 compares the OATI forecast, the delivered capability, and the *ex post* impact for the single FFR event. The Cadmus team found that the delivered capability of the single event was higher than both the OATI forecast and the *ex post* load impact. The poor performance of the forecast compared to the *ex post* impact was due to the minimal load reduction observed in the first interval of the event (interval starting 4:45AM). In the second interval of the event, the *ex post* impact was higher than the forecast. Without more FFR events, the team could not establish trends.

Figure 18. Comparison of FFR Forecast and Impacts



Forecast Trends

To answer a key research question—whether the 15-minute interval forecasts of capability produced by OATI improved over time—the Cadmus team assessed relevant trends on the basis of two metrics:

- Accuracy of the forecast of average capability for the event;
- Accuracy of the forecasts of capability for each 15 minute interval of the event.

The distinction here is critical, because while overall accuracy is important for quantifying the value of these grid services, event performance factors are dependent on accurate forecasts in each forecast period as described above. Figure 19 compares the by-event forecast error of each capacity build event and each capacity reduction event. The green trend line fits a time trend of the by-event forecast error, compared to the *ex post* impact results summarized above. Forecast accuracy for capacity build events fluctuated over time. However, there was a clear improvement in capacity reduction forecasts over time.

Figure 19. Capacity Build and Capacity Reduction Forecast Accuracy Trend, by Event

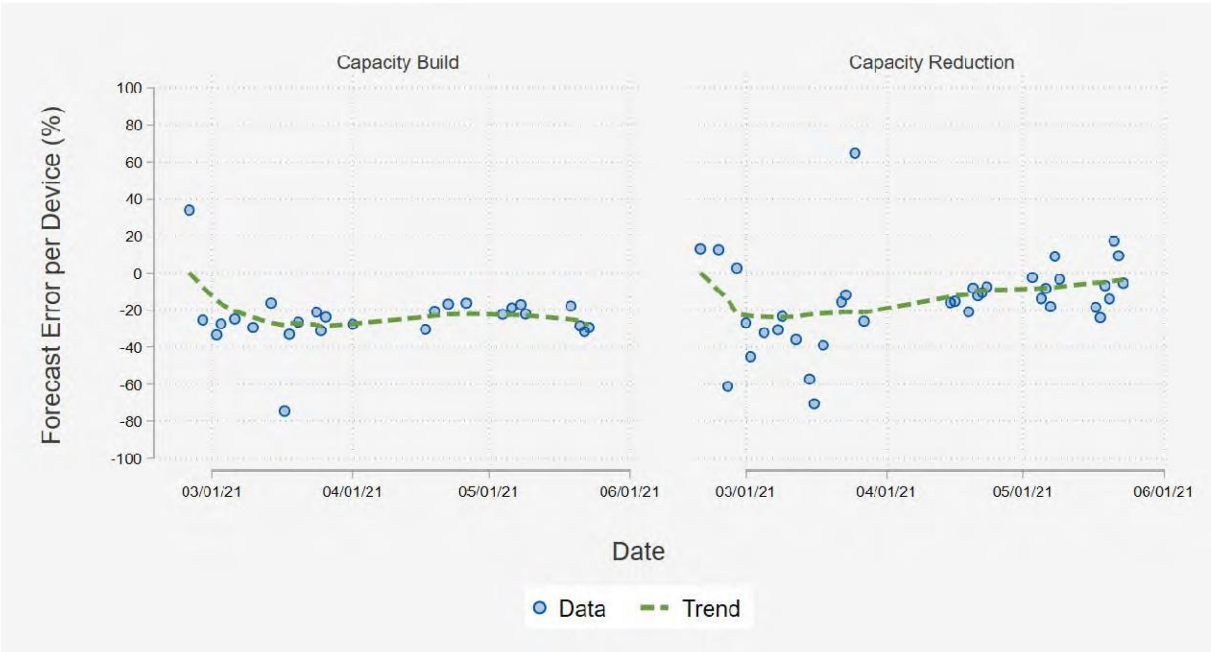
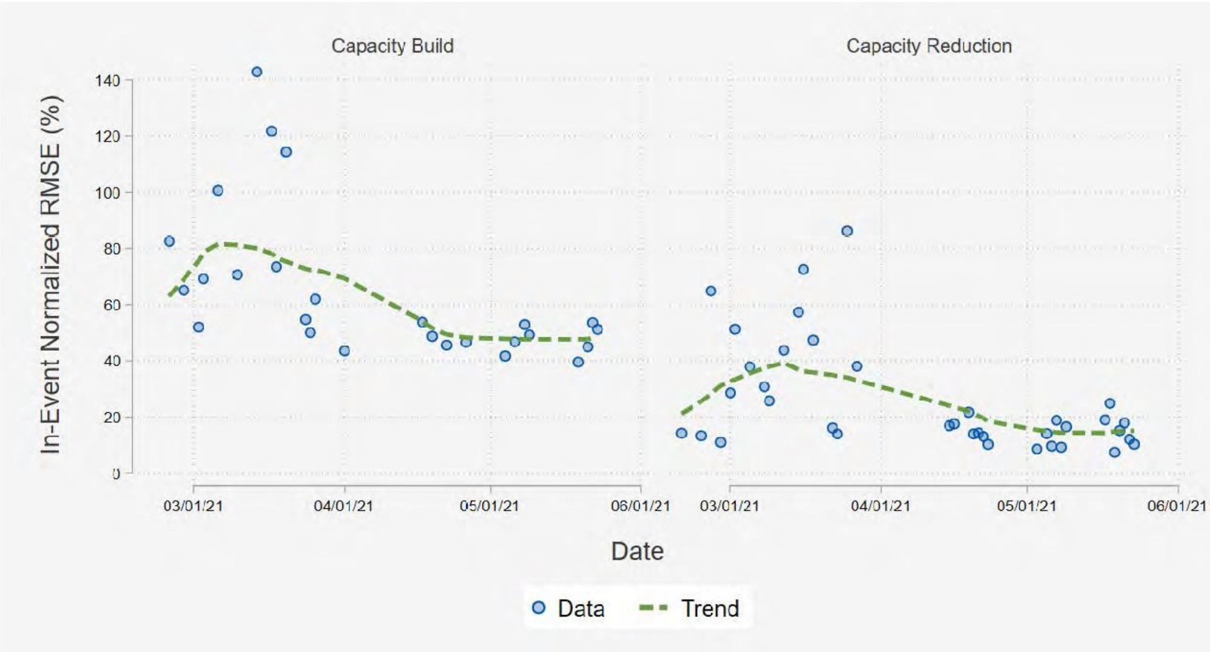


Figure 20 compares the within-event forecast error of each capacity build event and each capacity reduction event. The green trend line fits a time trend of the within-event forecast error—how well the forecast aligns with the *ex post* load impacts in each 15-minute interval of the event. Both capacity build and capacity reduction events showed improvements in forecast accuracy from the first half of the evaluation period to the second half, with reductions in the normalized root mean squared error over time.

Figure 20. Capacity Build and Capacity Reduction Forecast Accuracy Trend, within Event



A summary of the forecast accuracy by month and overall, by grid service, is shown in Table 7. More detailed findings are summarized in the appendix. The table below shows the average forecast error (% Error) as well as the normalized root mean squared error (RMSE) for events in each period. The average forecast error represents how much the forecast over- or under-states the true ex post impact, while the normalized RMSE represents the variability in forecast error from event to event. In both cases, a value closer to 0% represents more accurate and precise forecasts. For both capacity build and capacity reduction events, the forecast tended to understate the amount of load build or load shed available, while the forecast for the fast frequency response event overstated the amount of load shed available. For capacity build events, accuracy and precision fluctuated over time, especially in April of 2021, while the capacity reduce events showed a consistent improvement in accuracy and precision.

Table 7: Overall Forecast Accuracy Statistics for RCT Treatment Customers

Month	Grid Service	# of Events	Ex Post (kW)	Error (kW)	% Error	Norm RMSE (%)
Full RCT Period	Capacity Build	27	102.6	-22.6	-22.0	35.2
February	Capacity Build	2	91.2	-4.5	-4.9	28.7
March	Capacity Build	11	104.3	-32.7	-31.4	35.1
April	Capacity Build	6	90.1	-4.5	-5.0	51.6
May	Capacity Build	8	112.4	-26.6	-23.7	24.6
Full RCT Period	Capacity Reduction	37	216.6	-38.2	-17.6	28.9
February	Capacity Reduction	4	200.3	-28.1	-14.0	40.8
March	Capacity Reduction	13	218.3	-69.4	-31.8	40.1
April	Capacity Reduction	7	221.5	-29.2	-13.2	14.3
May	Capacity Reduction	13	217.2	-14.9	-6.9	13.7
Full RCT Period	Fast Frequency Response	1	45.4	7.4	16.3	16.3
March	Fast Frequency Response	1	45.4	7.4	16.3	16.3

Appendix A. Results Tables

The following section contains tables with additional detailed findings for relevant sections of this report, including the following information:

- **Reference Load:** the water heater baseline demand (kilowatt), that is, the electricity demand that would have occurred if the event had not been called or triggered.
- **Metered Load:** the water heater electricity demand as recorded in the water heater telemetry data provided by OATI.
- **Treatment Effect:** the estimate of the demand response grid services impact obtained from analysis of metered load data from the RCT. The Cadmus team estimated the impacts through regression analysis.
- **Standard Error:** the standard error of the regression-based estimate of the treatment effect.
- **Percentage Change in Demand:** the ratio of the estimated treatment effect to the reference load.

Capacity Build

Table A-1 shows estimated impacts, reference load, and metered load for each capacity build event. Table A-2 shows the total treatment impacts (based upon the total count of treatment group devices that had a telemetry data reading in the first interval of the event) for each event.

Table A-1. Capacity Build, Average Impact Per Treatment Group Water Heater

Date	Event Start	Event End	Reference Load (kW)	Metered Load (kW)	Treatment Effect (kW)	Std. Err (kW)	% Demand Increase
2/24/21	10:00 a.m.	2:00 p.m.	0.233	0.328	0.095	0.021	41%
2/27/21	10:00 a.m.	2:00 p.m.	0.277	0.459	0.182	0.024	66%
3/2/21	10:00 a.m.	2:00 p.m.	0.204	0.361	0.157	0.022	77%
3/3/21	10:00 a.m.	2:00 p.m.	0.209	0.354	0.144	0.023	69%
3/6/21	10:00 a.m.	2:00 p.m.	0.304	0.451	0.147	0.024	48%
3/10/21	10:00 a.m.	2:00 p.m.	0.208	0.368	0.160	0.022	77%
3/14/21	10:00 a.m.	2:00 p.m.	0.295	0.427	0.132	0.025	45%
3/17/21	10:00 a.m.	2:00 p.m.	0.207	0.372	0.165	0.023	80%
3/18/21	10:00 a.m.	2:00 p.m.	0.209	0.383	0.175	0.022	84%
3/20/21	10:00 a.m.	2:00 p.m.	0.275	0.434	0.160	0.023	58%
3/24/21	10:00 a.m.	2:00 p.m.	0.194	0.359	0.165	0.024	85%
3/25/21	10:00 a.m.	2:00 p.m.	0.189	0.368	0.179	0.025	95%
3/26/21	10:00 a.m.	2:00 p.m.	0.216	0.379	0.163	0.026	76%
4/1/21	10:00 a.m.	2:00 p.m.	0.178	0.354	0.176	0.023	98%
4/17/21	10:00 a.m.	2:00 p.m.	0.245	0.432	0.186	0.026	76%
4/19/21	10:00 a.m.	2:00 p.m.	0.183	0.344	0.161	0.023	88%
4/22/21	10:00 a.m.	2:00 p.m.	0.171	0.319	0.148	0.022	87%
4/25/21	10:00 a.m.	2:00 p.m.	0.248	0.236	-0.012	0.026	-5%
4/26/21	10:00 a.m.	2:00 p.m.	0.187	0.348	0.161	0.023	86%
5/4/21	10:00 a.m.	2:00 p.m.	0.160	0.326	0.167	0.022	104%
5/6/21	10:00 a.m.	2:00 p.m.	0.168	0.328	0.160	0.021	95%
5/8/21	10:00 a.m.	2:00 p.m.	0.235	0.395	0.160	0.023	68%
5/9/21	10:00 a.m.	2:00 p.m.	0.234	0.407	0.173	0.024	74%
5/19/21	10:00 a.m.	2:00 p.m.	0.178	0.342	0.164	0.022	92%
5/21/21	10:00 a.m.	2:00 p.m.	0.187	0.362	0.176	0.023	94%
5/22/21	10:00 a.m.	2:00 p.m.	0.220	0.408	0.189	0.024	86%
5/23/21	10:00 a.m.	2:00 p.m.	0.240	0.423	0.183	0.024	76%

Table A-2. Capacity Build Impacts for Treatment Group

Date	Event Start	Event End	Treatment Devices (n)	Reference Load (kW)	Treatment Effect (kW)	% Demand Increase
2/24/21	10:00 a.m.	2:00 p.m.	644	149.7	61.5	41%
2/27/21	10:00 a.m.	2:00 p.m.	652	180.7	118.4	66%
3/2/21	10:00 a.m.	2:00 p.m.	651	133.1	102.1	77%
3/3/21	10:00 a.m.	2:00 p.m.	652	136.6	94.0	69%
3/6/21	10:00 a.m.	2:00 p.m.	652	198.4	95.8	48%
3/10/21	10:00 a.m.	2:00 p.m.	656	136.3	105.2	77%
3/14/21	10:00 a.m.	2:00 p.m.	650	191.9	85.6	45%
3/17/21	10:00 a.m.	2:00 p.m.	648	134.0	107.0	80%
3/18/21	10:00 a.m.	2:00 p.m.	647	135.1	113.0	84%
3/20/21	10:00 a.m.	2:00 p.m.	650	178.6	103.7	58%
3/24/21	10:00 a.m.	2:00 p.m.	650	126.2	107.5	85%
3/25/21	10:00 a.m.	2:00 p.m.	650	123.0	116.3	95%
3/26/21	10:00 a.m.	2:00 p.m.	649	140.1	105.9	76%
4/1/21	10:00 a.m.	2:00 p.m.	649	115.8	114.0	98%
4/17/21	10:00 a.m.	2:00 p.m.	656	160.8	122.3	76%
4/19/21	10:00 a.m.	2:00 p.m.	654	119.8	105.1	88%
4/22/21	10:00 a.m.	2:00 p.m.	655	111.9	97.1	87%
4/25/21	10:00 a.m.	2:00 p.m.	661	164.2	-8.1	-5%
4/26/21	10:00 a.m.	2:00 p.m.	654	122.0	105.3	86%
5/4/21	10:00 a.m.	2:00 p.m.	653	104.3	108.8	104%
5/6/21	10:00 a.m.	2:00 p.m.	655	110.0	104.7	95%
5/8/21	10:00 a.m.	2:00 p.m.	652	153.2	104.1	68%
5/9/21	10:00 a.m.	2:00 p.m.	651	152.4	112.4	74%
5/19/21	10:00 a.m.	2:00 p.m.	649	115.8	106.1	92%
5/21/21	10:00 a.m.	2:00 p.m.	648	120.9	114.0	94%
5/22/21	10:00 a.m.	2:00 p.m.	648	142.3	122.3	86%
5/23/21	10:00 a.m.	2:00 p.m.	649	155.6	118.7	76%

Capacity Reduction

Table A-3 shows estimated impacts (treatment effect), reference load (baseline demand), and metered load (actual demand) for each capacity reduction event. Table A-4 shows the total treatment impacts (based upon the total count of treatment group devices that had a telemetry data reading in the first interval of the event) for each event.

Table A-3. Capacity Reduction, Average Impact Per Treatment Group Water Heater

Date	Event Start	Event End	Reference Load (kW)	Metered Load (kW)	Treatment Effect (kW)	Std. Err (kW)	% Demand Decrease
2/19/21	5:00 p.m.	6:00 p.m.	0.259	0.006	-0.253	0.006	-98%
2/23/21	5:00 p.m.	6:00 p.m.	0.274	0.014	-0.260	0.007	-95%
2/25/21	6:30 p.m.	7:30 p.m.	0.408	0.006	-0.402	0.007	-98%
2/27/21	5:00 p.m.	7:00 p.m.	0.316	0.003	-0.313	0.003	-99%
3/1/21	5:00 p.m.	6:00 p.m.	0.325	0.005	-0.320	0.006	-98%
3/2/21	6:00 p.m.	8:00 p.m.	0.423	0.010	-0.413	0.008	-98%
3/5/21	6:30 p.m.	7:30 p.m.	0.353	0.002	-0.351	0.003	-100%
3/8/21	6:00 p.m.	7:00 p.m.	0.425	0.021	-0.404	0.009	-95%
3/9/21	5:00 p.m.	7:00 p.m.	0.347	0.023	-0.324	0.008	-93%
3/12/21	7:00 p.m.	9:00 p.m.	0.369	0.002	-0.366	0.004	-99%
3/15/21	7:00 p.m.	8:00 p.m.	0.402	0.006	-0.396	0.008	-98%
3/16/21	5:00 p.m.	7:00 p.m.	0.300	0.006	-0.294	0.005	-98%
3/18/21	6:00 p.m.	8:00 p.m.	0.408	0.003	-0.405	0.006	-99%
3/22/21	5:00 p.m.	6:00 p.m.	0.290	0.001	-0.289	0.004	-100%
3/23/21	6:00 p.m.	7:00 p.m.	0.325	0.010	-0.315	0.007	-97%
3/25/21	6:00 p.m.	8:00 p.m.	0.385	0.240	-0.145	0.028	-38%
3/27/21	6:30 p.m.	7:30 p.m.	0.299	0.003	-0.296	0.004	-99%
4/15/21	5:00 p.m.	6:00 p.m.	0.291	0.007	-0.285	0.007	-98%
4/16/21	6:00 p.m.	8:00 p.m.	0.359	0.002	-0.357	0.005	-99%
4/19/21	6:00 p.m.	8:00 p.m.	0.404	0.004	-0.400	0.007	-99%
4/20/21	5:00 p.m.	6:00 p.m.	0.263	0.003	-0.259	0.004	-99%
4/21/21	6:00 p.m.	8:00 p.m.	0.357	0.001	-0.356	0.005	-100%
4/22/21	6:00 p.m.	8:00 p.m.	0.351	0.005	-0.347	0.006	-99%
4/23/21	7:00 p.m.	8:00 p.m.	0.355	0.010	-0.345	0.008	-97%
5/3/21	6:00 p.m.	7:00 p.m.	0.314	0.001	-0.313	0.005	-100%
5/5/21	5:30 p.m.	6:30 p.m.	0.309	0.000	-0.308	0.004	-100%
5/6/21	8:00 p.m.	9:00 p.m.	0.382	0.004	-0.377	0.007	-99%
5/7/21	5:30 p.m.	6:30 p.m.	0.276	0.001	-0.275	0.003	-100%
5/8/21	7:30 p.m.	8:30 p.m.	0.300	0.001	-0.299	0.003	-100%
5/9/21	7:00 p.m.	8:00 p.m.	0.336	0.003	-0.333	0.006	-99%
5/17/21	6:00 p.m.	7:00 p.m.	0.329	0.001	-0.328	0.006	-100%
5/18/21	7:00 p.m.	8:00 p.m.	0.438	0.003	-0.435	0.008	-99%
5/19/21	8:00 p.m.	9:00 p.m.	0.385	0.001	-0.384	0.007	-100%
5/20/21	5:30 p.m.	6:30 p.m.	0.319	0.007	-0.312	0.007	-98%
5/21/21	7:30 p.m.	8:30 p.m.	0.285	0.009	-0.276	0.007	-97%
5/22/21	7:00 p.m.	8:00 p.m.	0.294	0.008	-0.286	0.007	-97%
5/23/21	8:00 p.m.	9:00 p.m.	0.382	0.006	-0.376	0.007	-98%

Table A-4. Capacity Reduction Impacts for Treatment Group

Date	Event Start	Event End	Treatment Devices (n)	Reference Load (kW)	Treatment Effect (kW)	% Demand Decrease
2/19/21	5:00 p.m.	6:00 p.m.	640	165.9	-162.2	-98%
2/23/21	5:00 p.m.	6:00 p.m.	642	176.0	-166.9	-95%
2/25/21	6:30 p.m.	7:30 p.m.	649	264.6	-260.6	-98%
2/27/21	5:00 p.m.	7:00 p.m.	651	205.5	-203.5	-99%
3/1/21	5:00 p.m.	6:00 p.m.	652	211.8	-208.6	-98%
3/2/21	6:00 p.m.	8:00 p.m.	652	275.6	-269.2	-98%
3/5/21	6:30 p.m.	7:30 p.m.	649	228.8	-227.7	-100%
3/8/21	6:00 p.m.	7:00 p.m.	605	257.2	-244.6	-95%
3/9/21	5:00 p.m.	7:00 p.m.	652	226.3	-211.3	-93%
3/12/21	7:00 p.m.	9:00 p.m.	650	239.6	-238.0	-99%
3/15/21	7:00 p.m.	8:00 p.m.	649	261.1	-257.0	-98%
3/16/21	5:00 p.m.	7:00 p.m.	648	194.1	-190.5	-98%
3/18/21	6:00 p.m.	8:00 p.m.	649	264.8	-262.8	-99%
3/22/21	5:00 p.m.	6:00 p.m.	649	188.4	-187.5	-100%
3/23/21	6:00 p.m.	7:00 p.m.	647	210.4	-203.8	-97%
3/25/21	6:00 p.m.	8:00 p.m.	652	250.9	-94.3	-38%
3/27/21	6:30 p.m.	7:30 p.m.	647	193.5	-191.3	-99%
4/15/21	5:00 p.m.	6:00 p.m.	656	191.1	-186.8	-98%
4/16/21	6:00 p.m.	8:00 p.m.	653	234.3	-233.0	-99%
4/19/21	6:00 p.m.	8:00 p.m.	653	263.6	-261.0	-99%
4/20/21	5:00 p.m.	6:00 p.m.	655	172.1	-169.9	-99%
4/21/21	6:00 p.m.	8:00 p.m.	657	234.4	-233.6	-100%
4/22/21	6:00 p.m.	8:00 p.m.	655	230.0	-227.0	-99%
4/23/21	7:00 p.m.	8:00 p.m.	656	232.8	-226.1	-97%
5/3/21	6:00 p.m.	7:00 p.m.	654	205.6	-204.6	-100%
5/5/21	5:30 p.m.	6:30 p.m.	656	202.6	-202.3	-100%
5/6/21	8:00 p.m.	9:00 p.m.	655	250.0	-247.2	-99%
5/7/21	5:30 p.m.	6:30 p.m.	652	179.9	-179.3	-100%
5/8/21	7:30 p.m.	8:30 p.m.	651	195.0	-194.5	-100%
5/9/21	7:00 p.m.	8:00 p.m.	648	217.7	-215.7	-99%
5/17/21	6:00 p.m.	7:00 p.m.	644	211.7	-211.4	-100%
5/18/21	7:00 p.m.	8:00 p.m.	649	284.3	-282.3	-99%
5/19/21	8:00 p.m.	9:00 p.m.	650	250.3	-249.6	-100%
5/20/21	5:30 p.m.	6:30 p.m.	648	206.8	-202.2	-98%
5/21/21	7:30 p.m.	8:30 p.m.	651	185.8	-179.6	-97%
5/22/21	7:00 p.m.	8:00 p.m.	649	190.6	-185.5	-97%
5/23/21	8:00 p.m.	9:00 p.m.	652	249.3	-245.3	-98%

Evaluation of Settlement Calculation Methods

Table A-5 compares the OATI forecast for each event with the delivered capability of each event, for each capacity build event and each capacity reduction event. On some event days, both a capacity build event and a capacity reduction event were called. Table A-6 compares the OATI forecast with the delivered capability of the single FFR event.

Table A-5. Forecasted and Delivered Capability for Capacity Build and Capacity Reduction Events

Date	Devices	Capacity Build		Capacity Reduction	
		Forecast (kW)	Delivered Capability (kW)	Forecast (kW)	Delivered Capability (kW)
Feb 19, 2021	1,499			379.87	368.13
Feb 23, 2021	1,501			413.35	369.84
Feb 24, 2021	1,517	184.30	140.69		
Feb 25, 2021	1,538			312.49	537.79
Feb 27, 2021	1,548	195.93	218.62	452.00	401.37
Mar 01, 2021	1,549			424.61	380.20
Mar 02, 2021	1,549	176.47	174.82	406.31	508.87
Mar 03, 2021	1,557	191.72	171.14		
Mar 05, 2021	1,558			441.44	537.19
Mar 06, 2021	1,558	188.86	220.53		
Mar 08, 2021	1,560			509.47	462.37
Mar 09, 2021	1,561			455.76	410.05
Mar 10, 2021	1,562	201.28	184.78		
Mar 12, 2021	1,560			419.09	553.50
Mar 14, 2021	1,564	199.59	193.86		
Mar 15, 2021	1,564			307.89	554.03
Mar 16, 2021	1,564			314.43	455.35
Mar 17, 2021	1,562	133.55	202.36		
Mar 18, 2021	1,562	199.38	215.07	432.82	531.75
Mar 20, 2021	1,566	194.56	225.03		
Mar 22, 2021	1,563			406.82	404.39
Mar 23, 2021	1,565			488.99	482.08
Mar 24, 2021	1,568	219.41	176.07		
Mar 25, 2021	1,568	211.31	197.77	409.44	215.66
Mar 26, 2021	1,567	214.43	223.01		
Mar 27, 2021	1,566			376.31	482.30
Apr 01, 2021	1,567	225.05	197.80		
Apr 15, 2021	1,570			440.03	357.03
Apr 16, 2021	1,571			480.90	476.69
Apr 17, 2021	1,569	235.62	252.10		
Apr 19, 2021	1,571	224.18	216.86	508.25	465.82
Apr 20, 2021	1,570			443.75	364.98
Apr 21, 2021	1,570			502.23	463.30
Apr 22, 2021	1,573	220.23	173.61	502.13	465.40
Apr 23, 2021	1,573			447.73	491.87
Apr 25, 2021	1,571	239.37	-15.09		
Apr 26, 2021	1,571	225.81	247.38		
May 03, 2021	1,563			542.08	483.43

Date	Devices	Capacity Build		Capacity Reduction	
		Forecast (kW)	Delivered Capability (kW)	Forecast (kW)	Delivered Capability (kW)
May 04, 2021	1,566	224.83	214.64		
May 05, 2021	1,563			472.21	462.64
May 06, 2021	1,564	223.74	223.83	616.52	572.32
May 07, 2021	1,564			420.51	464.85
May 08, 2021	1,561	234.71	233.11	502.95	549.55
May 09, 2021	1,558	235.85	241.12	445.67	511.79
May 17, 2021	1,556			484.88	468.69
May 18, 2021	1,557			460.94	525.23
May 19, 2021	1,558	227.91	264.67	629.13	562.04
May 20, 2021	1,556			485.50	443.85
May 21, 2021	1,557	220.26	285.87	498.46	561.64
May 22, 2021	1,557	230.03	274.27	430.48	484.99
May 23, 2021	1,558	228.68	281.80	622.07	519.16

Table A-6. Forecasted and Delivered Capability for FFR Events

Date	Devices	Forecast (kW)	Delivered Capability (kW)
Mar 29, 2021	1,540	153.18	256.33

Assessment of Settlement Accuracy

Table A-7 compares the 5-minute load shapes on the average pseudo-event day between the observed telemetry data and the baseline estimates.

Table A-7. Capacity Build and Capacity Reduction Pseudo-Events

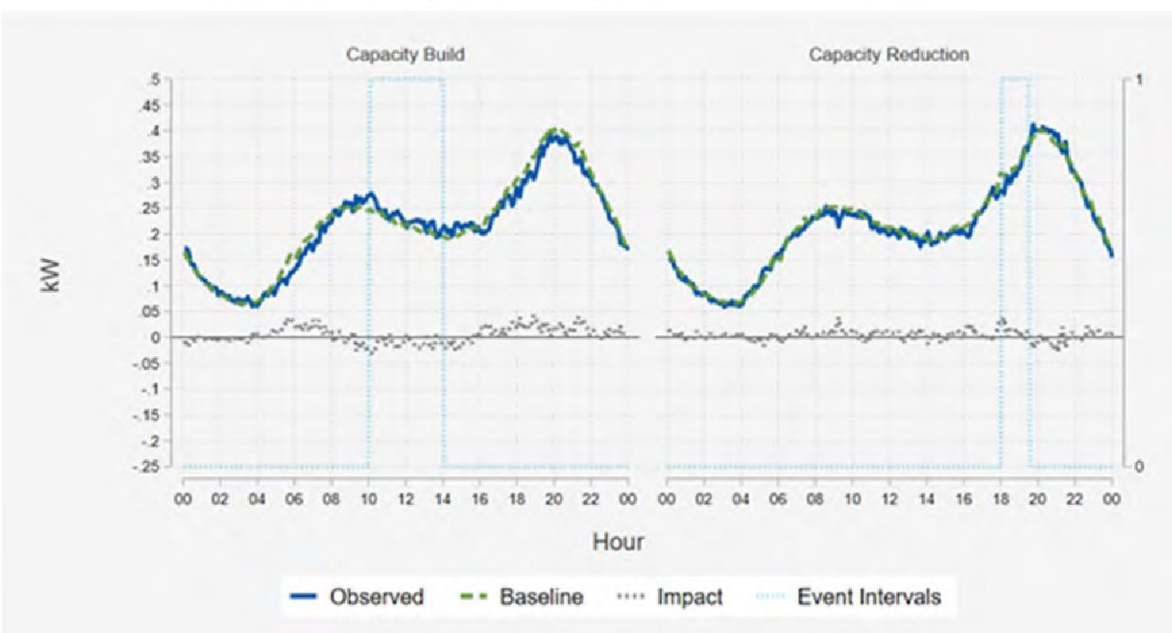


Table A-8 summarizes the observed usage in kilowatts and the baseline estimate in kilowatts for each pseudo-event, by date. On each date, the magnitude of the bias—in nominal kilowatts and on a percentage basis—is also shown.

Table A-8. Accuracy and Precision Results by Date

Pseudo-Event Date	Grid Service	Usage (kW)	Baseline (kW)	Bias (kW)	Bias (%)
Feb 20, 2021	Capacity Build	0.27	0.23	-0.03	-12.28
Feb 20, 2021	Fast Frequency Response	0.19	0.20	0.01	5.99
Mar 04, 2021	Capacity Build	0.20	0.25	0.05	22.91
Mar 04, 2021	Capacity Reduction	0.39	0.35	-0.03	-8.30
Mar 21, 2021	Capacity Build	0.29	0.24	-0.05	-15.99
Mar 21, 2021	Capacity Reduction	0.34	0.36	0.01	3.96
Apr 02, 2021	Fast Frequency Response	0.25	0.23	-0.02	-6.67
Apr 13, 2021	Capacity Reduction	0.34	0.33	0.00	-1.21
Apr 14, 2021	Fast Frequency Response	0.25	0.23	-0.02	-8.81
Apr 24, 2021	Capacity Build	0.25	0.21	-0.03	-13.63
Apr 24, 2021	Capacity Reduction	0.30	0.34	0.04	13.90
Apr 28, 2021	Fast Frequency Response	0.24	0.24	0.00	0.66
May 11, 2021	Capacity Reduction	0.30	0.34	0.04	11.98
May 11, 2021	Fast Frequency Response	0.22	0.22	0.00	-2.09
May 16, 2021	Capacity Reduction	0.31	0.32	0.02	5.26
May 24, 2021	Capacity Build	0.17	0.20	0.02	12.64
May 24, 2021	Capacity Reduction	0.33	0.32	0.00	-1.28
May 27, 2021	Capacity Reduction	0.28	0.31	0.03	10.01
May 29, 2021	Capacity Build	0.20	0.18	-0.02	-9.83

Assessment of Forecast Accuracy

Table A-9 summarizes the per-event forecast, delivered capability and *ex post* impact by date and event type on a per-device basis.

Table A-9. Forecast, Load Impacts, and Delivered Capability by Date

Date	Grid Service	Per-Device (kW)		
		Forecast	Delivered Capability	Ex Post Impact
Feb 19, 2021	Capacity Reduction	0.29	0.29	0.25
Feb 23, 2021	Capacity Reduction	0.29	0.29	0.26
Feb 24, 2021	Capacity Build	0.13	0.11	0.10
Feb 25, 2021	Capacity Reduction	0.16	0.42	0.40
Feb 27, 2021	Capacity Build	0.14	0.19	0.18
Feb 27, 2021	Capacity Reduction	0.32	0.31	0.31
Mar 01, 2021	Capacity Reduction	0.23	0.30	0.32
Mar 02, 2021	Capacity Build	0.10	0.15	0.16
Mar 02, 2021	Capacity Reduction	0.23	0.40	0.41
Mar 03, 2021	Capacity Build	0.10	0.14	0.14
Mar 05, 2021	Capacity Reduction	0.24	0.41	0.35
Mar 06, 2021	Capacity Build	0.11	0.18	0.15
Mar 08, 2021	Capacity Reduction	0.28	0.35	0.40
Mar 09, 2021	Capacity Reduction	0.25	0.32	0.32
Mar 10, 2021	Capacity Build	0.11	0.15	0.16

Date	Grid Service	Per-Device (kW)		
		Forecast	Delivered Capability	Ex Post Impact
Mar 12, 2021	Capacity Reduction	0.24	0.42	0.37
Mar 14, 2021	Capacity Build	0.11	0.16	0.13
Mar 15, 2021	Capacity Reduction	0.17	0.43	0.40
Mar 16, 2021	Capacity Reduction	0.09	0.33	0.29
Mar 17, 2021	Capacity Build	0.04	0.16	0.17
Mar 18, 2021	Capacity Build	0.12	0.17	0.17
Mar 18, 2021	Capacity Reduction	0.25	0.40	0.40
Mar 20, 2021	Capacity Build	0.12	0.17	0.16
Mar 22, 2021	Capacity Reduction	0.24	0.30	0.29
Mar 23, 2021	Capacity Reduction	0.28	0.36	0.32
Mar 24, 2021	Capacity Build	0.13	0.15	0.17
Mar 25, 2021	Capacity Build	0.12	0.15	0.18
Mar 25, 2021	Capacity Reduction	0.24	0.16	0.14
Mar 26, 2021	Capacity Build	0.12	0.16	0.16
Mar 27, 2021	Capacity Reduction	0.22	0.36	0.30
Mar 29, 2021	Fast Frequency Response	0.08	0.16	0.07
Apr 01, 2021	Capacity Build	0.13	0.14	0.18
Apr 15, 2021	Capacity Reduction	0.24	0.27	0.28
Apr 16, 2021	Capacity Reduction	0.30	0.36	0.36
Apr 17, 2021	Capacity Build	0.13	0.17	0.19
Apr 19, 2021	Capacity Build	0.13	0.15	0.16
Apr 19, 2021	Capacity Reduction	0.32	0.35	0.40
Apr 20, 2021	Capacity Reduction	0.24	0.28	0.26
Apr 21, 2021	Capacity Reduction	0.31	0.36	0.36
Apr 22, 2021	Capacity Build	0.12	0.13	0.15
Apr 22, 2021	Capacity Reduction	0.31	0.35	0.35
Apr 23, 2021	Capacity Reduction	0.32	0.37	0.34
Apr 25, 2021	Capacity Build	0.14	-0.02	-0.01
Apr 26, 2021	Capacity Build	0.13	0.16	0.16
May 03, 2021	Capacity Reduction	0.31	0.33	0.31
May 04, 2021	Capacity Build	0.13	0.14	0.17
May 05, 2021	Capacity Reduction	0.27	0.33	0.31
May 06, 2021	Capacity Build	0.13	0.15	0.16
May 06, 2021	Capacity Reduction	0.35	0.40	0.38
May 07, 2021	Capacity Reduction	0.23	0.33	0.28
May 08, 2021	Capacity Build	0.13	0.15	0.16
May 08, 2021	Capacity Reduction	0.33	0.38	0.30
May 09, 2021	Capacity Build	0.13	0.16	0.17
May 09, 2021	Capacity Reduction	0.32	0.35	0.33
May 17, 2021	Capacity Reduction	0.27	0.32	0.33
May 18, 2021	Capacity Reduction	0.33	0.36	0.44
May 19, 2021	Capacity Build	0.13	0.17	0.16
May 19, 2021	Capacity Reduction	0.36	0.39	0.38
May 20, 2021	Capacity Reduction	0.27	0.31	0.31
May 21, 2021	Capacity Build	0.13	0.19	0.18
May 21, 2021	Capacity Reduction	0.32	0.38	0.28
May 22, 2021	Capacity Build	0.13	0.17	0.19
May 22, 2021	Capacity Reduction	0.31	0.34	0.29
May 23, 2021	Capacity Build	0.13	0.19	0.18
May 23, 2021	Capacity Reduction	0.36	0.36	0.38

	EnergyScout	Fast DR	GSPA	Battery Bonus
Description	Traditional DR program using residential and small business water heating and A/C cycling and large C&I transitioning to generating resources	Load shed for C&I customers with 50kW+ of available demand reduction	Aggregators deliver a contracted amount of Grid Services	Scheduled peak dispatch of batteries paired with solar
Grid Services	Capacity Reduction FFR	Capacity Reduction	Capacity Reduction Capacity Build FFR	Capacity Reduction
Customer Incentive Type	Residential: Fixed monthly incentive C&I: $/kW monthly performance-based incentive	$/kW monthly performance-based incentive	$/kW fixed monthly incentive per Grid Service	$/kW onetime, upfront incentive
Enrollment	29,195 residential water heaters 3,701 residential A/C 204 C&I and SMB customers	17 customers HECO 30 customers MECO	HECO Capacity Build and Reduction, FFR = 1156 MECO Capacity Build and Reduction = 36	460 applications submitted (as of Oct 2021)
# of Events (A&S 2020)	26 (residential) 12 (C&I and small business)	16 (HECO) 1 (MECO)	68 (HECO) 0 (MECO)	N/A
Capacity Reduction (2020 A&S)	25.4 MW (HECO only)	4.3 MW (HECO) 4.9 MW (MECO)	1.2 MW (HECO) 10 kW (MECO)	1.7 MW pending installation (as of Oct 2021)

<u>EnergyScout:</u> Programs include residential and commercial direct load control options. Residential participant incentives are $3/water heater/month and $5/central AC/month. Small and medium business participants receive $5/water heater/month and $5/AC ton/month. Large Commercial participants receive a monthly incentive based on their performance during events. Participants receive $5/kw for Capacity Reduction and $10/kw for Capacity Reduction and FFR.

<u>Fast DR:</u> Fast DR provides an incentive to customers to enable their equipment to participate in the program. The enablement process includes and audit and equipment installations or upgrades. Audits typically cost $2500 and an average of $250/kW for capacity committed to the program is offered to assist in covering installation and upgrade costs. Participants receive a monthly performance based $/kW incentive for the capacity committed to the program depending on their enrollment option. For Oʻahu a customer can enroll in 40 events annually for $5/kW or 80 events annually for $10/kW. Maui Fast DR offers $5/kW for 40 events annually.

GSPA: Participants under the GSPA are guaranteed a minimum monthly incentive per Grid Service they are enrolled in. A participant enrolled in FFR receives $5/kW, in Capacity Reduction receives $5/kW, or in Capacity Build receives $3/kW. Aggregators are awarded GSPAs under a public RFP process. Per the GSPA, aggregators receive a onetime $/kW payment for each enabled kW and ongoing monthly management payments based on delivery performance of each Grid Service.

Battery Bonus: Participants designate a committed capacity that will be discharged from their Battery Energy Storage System ("BESS") for two hours during peak time. The program capacity is 50MW. For the first 15MWs enrolled, participants receive $850/kW, for the next 15MWs participants receive $750/kW, for the remaining 20MW participants receive $500/kW.